December 2002

Sacramento and San Joaquin River Basins Comprehensive Study

# TECHNICAL STUDIES DOCUMENTATION

## APPENDIX C

## RESERVOIR OPERATIONS MODELING
## Existing Design Operations and Reoperation Analyses

The Reclamation Board, State of California — Public Safety with Flood Protection

US Army Corps of Engineers
Sacramento District

# Expectations of Use

## Reservoir Operation Models
## Developed Specifically for the Comprehensive Study

**Purpose of Models:** The Sacramento and San Joaquin River Basins Comprehensive Study models are excellent representations of the existing flood control system and were developed specifically for use in regional, broad concept studies, such as the Comprehensive Study. As developed, they are capable of facilitating the technical needs of other studies; however, their level of detail offers only enough detail for pre-feasibility applications and hence may or may not completely fulfill those needs. In most applications, more detailed models will need to be developed for site-specific applications.

The Hydrologic Engineering Center's HEC-5 software (Simulation of Flood Control and Conservation Systems) used for the models is designed to perform sequential reservoir operation based on specified project demands and constraints. It can simulate any dendritic reservoir system configuration of streams, weirs, bypasses, and storage areas within the dimension limits of the version being used. HEC-5 version 8.0 (May 2000), which includes the executable modifications added in January 2002, was used as the operating platform to conduct the reservoir operation modeling. HEC-5 provides a means both for understanding and representing the flood management systems for the Sacramento and San Joaquin river systems.

Four separate HEC-5 models were developed: two for the Sacramento River system and two for the San Joaquin River system. In each set, one of the models represents the headwater reservoirs and the second represents the lower basin flood control facilities. The HEC-5 models were constructed to allow modeling of flood flow conditions and were used to develop tributary contributions to the mainstems of both the Sacramento and San Joaquin rivers. Output from them was then used for subsequent analyses of floodplain and channel hydraulics using the Sacramento and San Joaquin River Basins Comprehensive Study UNET models.

For more information about the capabilities of the HEC-5 simulation program, refer to the October 1998 User's Manual and the December 2002 Comprehensive Study Reservoir Operation Models User's Guide.

**Responsibility of Users:**

1) Users may provide comments and feedback regarding model construction, coding errors, etc. to the Water Management Section of the Corps of Engineers. The point of contact is:

Mr. Robert Collins, District Hydrologist
U.S. Army Corps of Engineers
Sacramento District
(916) 557-7132

2) These complex and intricate models require application by qualified hydrologic/hydraulic engineers and scientists familiar with the HEC-5 simulation program. Professional judgment and expertise should be exercised for all analyses conducted using them. The U.S. Army Corps of Engineers and the California State Department of Water Resources do not provide technical support for these models.

**Basic Assumptions and Limitations:** The HEC-5 program is used to simulate the sequential operation of a system of reservoirs for short-interval historical or synthetic floods, for long duration non-flood periods, or combinations of the two. The models developed for the Comprehensive Study analysis were created with the following assumptions and limitations:

- They were created for use only with the synthetic 30-day hourly hydrographs developed specifically for the Comprehensive Study. To simulate other time steps or series, adjustments may need to be made.

- FEMA requires the starting storage of any headwater reservoir be established as that reservoir's gross pool; however, the Comprehensive Study simulations establish starting storages of the headwater reservoirs as an average of their storages during the '97, '95, and '86 storm events. If the average storage was greater than gross pool, then gross pool was used as the starting storage. Starting storage of the lower basin flood control reservoirs is the top of conservation.

- Top of conservation of lower basin reservoirs assumes a maximum basin wetness to assure the maximum available flood space.

- Guidelines established within each reservoir's water control manual were strictly observed.

- Some reservoirs with stepped release schedules rely on both the percentage of required flood control space used and peak inflow in determining flood releases. For these reservoirs, fixed percentages of required flood control space used were assumed.

- Muskingum routing parameters are fixed for all simulated exceedence frequencies.

- Local flows were either produced through procedures outlined in *Appendix B Synthetic Hydrology Technical Documentation* or assumed to be a ratio of the short duration maxima of a nearby natural flow hydrograph. These ratios are not scaled for each simulated exceedence frequency.

- Calibration and verification were accomplished using the '95 and '97 flood events and by comparing these to manual routings published in water control manuals.

- There are no losses simulated within the model: no evaporation, no groundwater infiltration or seepage, and no levee breaks.  The models assume an infinite channel capacity.

- There was difficulty in concisely integrating some of the operating criteria of specific reservoirs.  The multi-parameter "Release Schedules" of Black Butte and Oroville had to be written into the model by assuming one of the variable parameters to be constant.  Similar difficulties required that an operational point for Black Butte Dam (Ord Ferry) be excluded from the simulations.  Complications in utilizing the forecast capabilities of HEC-5 required that one of the operating points of Friant Dam be located outside of the program's forecast window.

- The simulation program assumes near certainty in flow contributions from downstream tributaries when operating facilities for flows at that location or downstream of that location.

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## REFERENCES

CALFED Bay-Delta Program, Sacramento, *Initial Surface Water Storage Screening.* August, 2000.

Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, *Technical Memorandum 4, Draft Long List of Alternatives, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River*. Nov 22, 2000.

U.S. Army Corps of Engineers, *HEC-5 Users Manual Version 8.0*. Hydrologic Engineering Center. Davis, California. 1998

U.S. Army Corps of Engineers, *Reservoir System Analysis*. Hydrologic Engineering Center. Davis, California. 1999.

U.S. Army Corps of Engineers, Sacramento District, *Sacramento and San Joaquin River Basin, Post-Flood Assessment*. March 1999.

U.S. Army Corps of Engineers, *Tuolumne River Feasibility Study*.

Wave Engineers, Inc, *Fine Gold Water Conservation Project, Initial Operations Study*. February, 1991.

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# CHAPTER I

# INTRODUCTION

## AUTHORITY

In response to extensive flooding and damages experienced in 1997, the United States Congress authorized the U.S. Army Corps of Engineers, Sacramento District (USACE) to provide a comprehensive analysis of the Sacramento and San Joaquin river basin flood management systems and to partner with the State of California to develop master plans for flood damage reduction. The USACE and the State Reclamation Board of California are leading this Comprehensive Study to improve flood management and integrate ecosystem restoration in the Sacramento and San Joaquin river basins.

The authorization for the Comprehensive Study directed the development of hydrologic and hydraulic models for both river basins that will allow systematic evaluation. These models incorporate reservoir operations and flow along the major river systems to evaluate the performance of the flood management systems. The models can be used to assess the performance of the current systems or modified systems under a wide range of hydrologic conditions.

## PURPOSE OF DOCUMENTATION

This report documents the work conducted for the Sacramento and San Joaquin River Basins Comprehensive Study to develop reservoir operation models, specifically Phase II – Model Refinement and Simulation of both existing operational conditions and evaluation of flood management alternatives. The main product components of this effort include: HEC-5 Reservoir Operation Models for the Sacramento and San Joaquin River basins, which will include headwater and major flood management reservoirs.

The first part of this document is limited to the use of reservoir models to identify and describe baseline conditions. It does not include the formulation or evaluation of flood management alternatives. The performance of modified flood management strategies is addressed within subsequent sections of this document. Future work will continue to use these models in the analysis of alternatives for reducing flood damages in California's Central Valley.

## STUDY AREA

The study area encompasses the watersheds of the two major river systems of California's Central Valley, the Sacramento River in the north and the San Joaquin River in the south. These river systems comprise a combined drainage area of over 43,000 square miles, an area nearly as large as the state of Florida.

Due to its climate and geography, flooding is a frequent and natural event in the Central Valley. Historically, the Sacramento River Basin has been subject to floods that result from winter and spring rainfall as well as rainfall combined with snowmelt. The San Joaquin River Basin has been subject to floods that result from both rainfall that occurs during the late fall and winter months, and melting of the winter snowpack during the spring and early summer months.

# CHAPTER II

# RESERVOIR MODELING BACKGROUND

## GENERAL

The technical process for the hydrologic and hydraulic investigations of the Sacramento and San Joaquin River Basins Comprehensive Study is comprised of three interrelated parts: 1) Development of Synthetic Hydrology (Appendix B); 2) Reservoir Operations Modeling (Appendix C); and 3) Hydraulic Modeling of Floodplain Areas (Appendix D), as shown in Figure II-1. This report documents Phase II reservoir modeling efforts and presents the results of system-wide reservoir simulations and evaluation of proposed flood management operation alternatives.

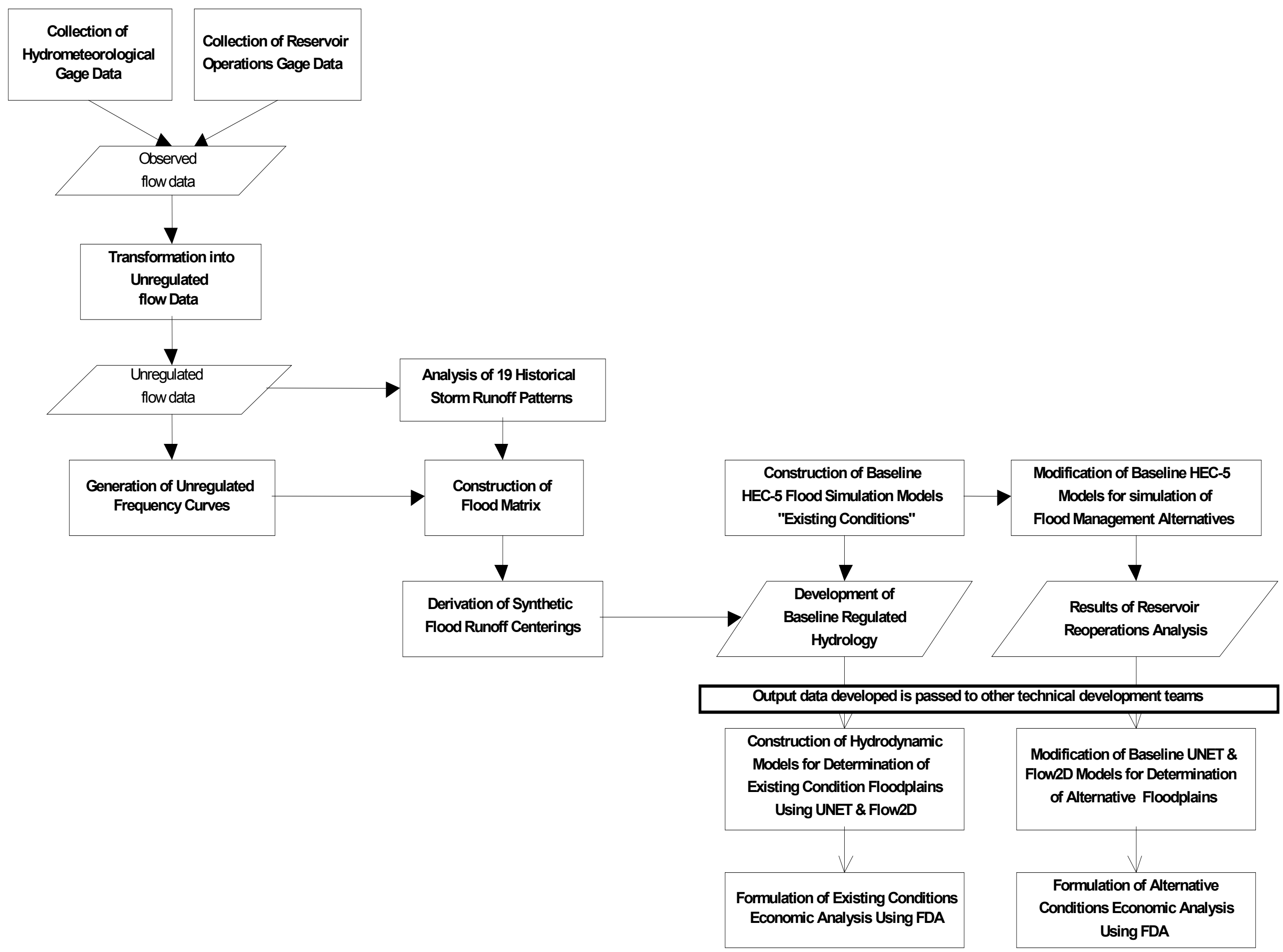
Phase I modeling began in 1998, immediately after the Comprehensive Study was authorized. The reservoir simulation model selected for use was *HEC-5: Simulation of Flood Control and Conservation Systems*. HEC-5, a computer program first developed and distributed in 1973, was designed by the Hydrologic Engineering Center (HEC) to offer guidance in real-time reservoir release decisions and to aid in planning studies for proposed reservoirs, operation alternatives, and flood space allocation (HEC-5 Users Manual Version 8.0, 1998).

An HEC-5 model is constructed using operational criteria input by the modeler. The program is designed to accept criteria related to flood operations, hydropower generation, river routings, diversions, and low-flow operations. Simulations can be performed using any time step. HEC-5 is the U.S. Army Corps of Engineers' (USACE) standard tool in reservoir analyses.

In support of the Water Management Section of the Sacramento District, USACE, HEC undertook Phase I development of HEC-5 models for flood damage reduction reservoirs within the Central Valley. At the conclusion of Phase I, HEC provided the Water Management Section with a report documenting the development of working models for the Sacramento Basin, which then included five flood damage reduction reservoirs, and for the San Joaquin Basin, which then included thirteen flood damage reduction reservoirs (Reservoir System Analysis, 1999).

Phase II reservoir modeling began in July 1999 and was performed by the Water Management Section. Efforts focused on refining and expanding the working models provided by HEC into calibrated models capable of performing reservoir simulations for the entire watershed. Fundamental changes to the Phase I models included the addition of spillway gate operations; detailed modeling of local flows; a philosophical shift from modeling verification using past events, to verification using established operational criteria found in each reservoir's Water Control Manual; and an overall expansion of the models from the original 18 reservoirs to a final tally of 73.

# FIGURE II-1 HYDROLOGY AND MODELING DEVELOPMENT PROCESS SCHEMATIC




*Note: Prior to use and application, reference the "Expectations of Use" preface.*

In support of the Comprehensive Study, Water Management performed reservoir simulations for the 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedence flood events. The seven synthetic exceedence frequency inflows to the reservoirs were computed in the Synthetic Hydrology Analysis (Appendix B – Synthetic Hydrology). Results from the HEC-5 simulations have been used in the hydraulic modeling and delineation of composite floodplain areas for each basin (Appendix D - Hydraulics). Results of the floodplain analyses have been fed into the stage-frequency relationships that drive the model estimating economic damages incurred during each of the seven synthetic exceedence flood runoff events. This entire process, from hydrology to economics, defines the "without-project conditions" needed for Comprehensive Study plan formulation.

Preparation of the reservoir models was undertaken with two goals in mind. The first goal was to accurately depict without-project conditions, thereby providing a solid frame of reference for analyses of potential improvements to the current flood damage reduction system. The second goal was to assure that the models used to define the baseline have the ability to analyze alternatives efficiently. In other words, the reservoir models were to be developed to have value beyond the definition of baseline conditions.

## SACRAMENTO AND SAN JOAQUIN RIVER BASIN RESERVOIRS

All reservoirs with gross pool storage greater than 10,000 acre-feet located in the Sacramento River Basin are shown in Plate 1. All reservoirs with gross storage greater than 10,000 acre-feet in the San Joaquin River Basin are shown in Plate 2. A tabular listing of all reservoirs in the Sacramento and San Joaquin River Basin is shown in Table II-1 (note: Identification numbers for each reservoir shown in Plates corresponds to identification numbers listed in tables for each reservoir).

# TABLE II-1

# INVENTORY OF RESERVOIRS IN THE SACRAMENTO AND SAN JOAQUIN RIVER BASINS

| # | Reservoir | Drainage | Owner | Gross Pool Storage (ac-ft) | DA[1] (mi²) | DOB[2] | Purpose |
|---|---|---|---|---|---|---|---|
| 1 | Antelope | Indian Creek | DWR | 22,566 | 71 | 1946 | Water Supply |
| 2 | Beardsley | Mfk Stanislaus River | Oakdale So San Joaquin ID | 77,600 | 308.5 | 1957 | Hydropower |
| 3 | Big Dry Creek | Big Dry Crk & Dog Crk | Fresno Metropolitan Fc Dist | 30,200 | 82 | 1948 | |
| 4 | Big Sage Reservoir | Rattlesnake Crk | Hot Spring Valley Irrigation Dist. | 77,000 | 107 | 1921 | |
| 5 | Black Butte | Stony Creek | USACE | 143,700 | 741 | 1963 | Flood Management |
| 6 | Bowman | Canyon Creek | Nevada Irrigation District | 64,000 | 28.91 | 1927 | Water Supply, Hydropower |
| 7 | Box Canyon | Sacramento River | Siskiyou County FCWCD | 26,000 | 126 | 1969 | Water Supply |
| 8 | Buchanan | Chowchilla River | USACE | 150,000 | 235 | 1975 | Flood Management |
| 9 | Bucks Storage | Bucks Creek | Pac Gas And Electric Co | 103,000 | 29.5 | 1928 | |
| 10 | Buena Vista | Offstream | J Boswell Co & Tenneco West | 205,000 | 373 | 1890 | |
| 11 | Burns | Burns Creek | USACE | 6,800 | 74 | 1950 | |
| 12 | Butt Valley | Butt Creek | Pac Gas And Electric Co | 49,800 | 86.2 | 1924 | |
| 13 | Camanche | Mokelumne River | East Bay Municipal District | 417,124 | 619 | 1963 | Flood Management |
| 14 | Camp Far West | Bear River | South Sutter Water Dist | 103,000 | 285 | 1963 | |
| 15 | Caples Lake | Tr Silver Fork | Pac Gas And Electric Co | 21,581 | 13 | 1922 | |
| 16 | Cherry Valley | Cherry Creek | City County San Francisco | 273,500 | 114 | 1956 | Water Supply, Hydropower |
| 17 | Clear Lake Imp | Cache Creek | Yolo County FCWC District | 315,000 | 514 | 1914 | |
| 18 | Courtright | Helms Creek | Pac Gas And Electric Co | 123,300 | 39.2 | 1958 | Water Supply, Hydropower |
| 19 | Crane Val Stor/Bass Lake | Nfk San Joaquin River | Pac Gas And Electric Co | 45,410 | 51.4 | 1910 | Water Supply, Hydropower |
| 20 | Don Pedro | Tuolumne River | Turlock Irrigation District | 2,030,000 | 1542 | 1971 | Flood Management |
| 21 | Donnells | Mfk Stanislaus River | Oakdale So San Joaquin ID | 56,893 | 229 | 1958 | Hydropower |
| 22 | East Park | Little Stony Creek | US Bureau Of Reclamation | 51,000 | 102 | 1910 | Water Supply |
| 23 | Englebright | Yuba River | USACE | 70,000 | 1100 | 1941 | |
| 24 | Farmington | Littlejohn Creek | USACE | 52,000 | 212 | 1951 | Flood Management |
| 25 | Florence Lake | Sfk San Joaquin River | Southern California Edison Co | 64,406 | 171 | 1926 | Water Supply, Hydropower |
| 26 | Folsom | American River | US Bureau Of Reclamation | 1,010,000 | 1885 | 1956 | Flood Management |
| 27 | French Lake | Canyon Creek | Nevada Irrigation District | 12,500 | 5.3 | 1859 | |
| 28 | Frenchman | Last Chance Creek | DWR | 55,477 | 82 | 1961 | Water Supply |
| 29 | Friant | San Joaquin River | US Bureau Of Reclamation | 520,500 | 1675 | 1942 | Flood Management |
| 30 | Grizzly Valley/Lake Davis | Big Grizzly Creek | DWR | 83,000 | 44 | 1966 | Water Supply |
| 31 | Hidden | Fresno River | USACE | 90,000 | 234 | 1975 | Flood Management |
| 32 | Homestake Tails | Tr Hunting Crk | Homestake Mining Company | 20,160 | 1.56 | 1990 | |
| 33 | Huntington Lake 1 | Big Creek | Southern California Edison Co | 88,834 | 80.4 | 1917 | Water Supply, Hydropower |
| 34 | Ice House | Sfk Silver Creek | Sacramento Muni Utility Dist | 37,120 | 28.4 | 1959 | Water Supply, Hydropower |
| 35 | Indian Ole (Mtn Meadows) | Hamilton Creek | Pac Gas And Electric Co | 24,800 | 158 | 1924 | |

Notes:

1. Drainage area (DA) in square miles
2. Completion date of dam and beginning of operation (DOB)

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE II-1

# INVENTORY OF RESERVOIRS IN THE SACRAMENTO AND SAN JOAQUIN RIVER BASINS

| # | Reservoir | Drainage | Owner | Gross Pool Storage (ac-ft) | DA[1] ($mi^2$) | DOB[2] | Purpose |
|---|---|---|---|---|---|---|---|
| 36 | Indian Valley | Nfk Cache Creek | Yolo County FCWC District | 300,000 | 122 | 1976 | Flood Management |
| 37 | Iron Canyon Reservoir | Iron Canyon Creek | Pac Gas And Electric Co | 24,300 | 11.2 | 1965 | |
| 38 | Isabella | Kern River | USACE | 568,000 | 2074 | 1953 | Flood Management |
| 39 | Jackson Creek | Jackson Creek | Jackson Valley Irrigation Dist | 22,000 | 58 | 1965 | |
| 40 | Jackson Meadows | Mfk Yuba River | Nevada Irrigation District | 52,500 | 37.11 | 1965 | Surcharge Storage |
| 41 | Jamestown Mines T | Tr Woods Creek | Sonora Mining Corporation | 12,100 | 0.37 | 1991 | |
| 42 | Keswick | Sacramento River | US Bureau Of Reclamation | 23,772 | 1950 | 1950 | |
| 43 | Lake Almanor | Nfk Feather Creek | Pac Gas And Electric Co | 1,308,000 | 503 | 1959 | |
| 44 | Lake Eleanor | Eleanor Creek | City County San Francisco | 27,800 | 79 | 1918 | Water Supply, Hydropower |
| 45 | Lake Fordyce | Fordyce Creek | Pac Gas And Electric Co | 48,900 | 30.15 | 1926 | Water Supply, Hydropower |
| 46 | Lake Kaweah/Terminus | Kaweah River | USACE | 143,000 | 561 | 1962 | Flood Management |
| 47 | Lake Spaulding | Sfk Jackson Creek | Pac Gas And Electric Co | 74,773 | 118 | 1901 | Water Supply, Hydropower |
| 48 | Little Grass Valley | Sfk Feather River | Oroville Wyandotte ID | 93,010 | 27.3 | 1961 | Water Supply |
| 49 | Ll Anderson/French Meadows | Mfk American River | Placer County Water Agency | 136,405 | 47.2 | 1965 | Water Supply, Hydropower |
| 50 | Loon Lake | Gerle Creek | Sacramento Muni Utility Dist | 76,500 | 8.1 | 1963 | Water Supply, Hydropower |
| 51 | Los Banos Detention | Los Banos Creek | US Bureau Of Reclamation | 34,600 | 160 | 1965 | Flood Management |
| 52 | Lower Bear River | Bear River | Pac Gas And Electric Co | 52,025 | 37 | 1952 | |
| 53 | Lower Hell Hole | Rubicon River | Placer County Water Agency | 208,400 | 114 | 1966 | Water Supply, Hydropower |
| 54 | Main Strawberry | Sk Stanislaus River | Pac Gas And Electric Co | 16,590 | 26.6 | 1916 | |
| 55 | Mammoth Pool | San Joaquin River | Southern California Edison Co | 123,000 | 998 | 1960 | Water Supply, Hydropower |
| 56 | Mariposa | Mariposa Creek | USACE | 15,000 | 107 | 1948 | |
| 57 | Mark Edson/Stumpy Meadows | Pilot Creek | Georgetown Divide Pud | 20,000 | 15.6 | 1962 | |
| 58 | McCloud | McCloud River | Pac Gas And Electric Co | 35,300 | 380 | 1965 | |
| 59 | Modesto Res | Tr Tuolumne River | Modesto Irrigation Dist | 29,000 | 10 | 1911 | |
| 60 | Monticello | Putah Creek | US Bureau Of Reclamation | 1,602,000 | 576 | 1957 | |
| 61 | New Bullards Bar | No. Yuba River | Yuba County Water Agency | 969,600 | 481 | 1970 | Flood Management |
| 62 | New Exchequer | Merced River | Merced Irrigation District | 1,032,000 | 1041 | 1967 | Flood Management |
| 63 | New Hogan | Calaveras River | USACE | 317,000 | 363 | 1963 | Flood Management |
| 64 | New Melones | Stanislaus River | US Bureau Of Reclamation | 2,400,000 | 900 | 1979 | Flood Management |
| 65 | New Spicer Meadow | Highland Creek | Calaveras Co Water District | 189,000 | 46.63 | 1989 | Hydropower |
| 66 | North Fork | Nfk Americn River | USACE | 14,700 | 343 | 1939 | |
| 67 | H. Hetchy /O Shaughnessy | Tuolumne Creek | City County San Francisco | 360,000 | 459 | 1923 | Water Supply, Hydropower |
| 68 | O'Neill | San Luis Creek | US Bureau Of Reclamation | 56,400 | 18 | 1967 | |
| 69 | Oroville | Feather River | DWR | 3,537,577 | 3607 | 1968 | Flood Management |
| 70 | Paradise | Little Butte Creek | Paradise Irrigation Dist | 11,500 | 8.66 | 1957 | |

Notes:

1. Drainage area (DA) in square miles
2. Completion date of dam and beginning of operation (DOB)

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE II-1

# INVENTORY OF RESERVOIRS IN THE SACRAMENTO AND SAN JOAQUIN RIVER BASINS

| # | Reservoir | Drainage | Owner | Gross Pool Storage (ac-ft) | DA[1] ($mi^2$) | DOB[2] | Purpose |
|---|---|---|---|---|---|---|---|
| 71 | Pardee | Mokelumne River | East Bay Municipal District | 210,000 | 575 | 1929 | Flood Management |
| 72 | Pine Flat | Kings River | USACE | 1,000,000 | 1545 | 1954 | Flood Management |
| 73 | Pit No 3 | Pit River | Pac Gas And Electric Co | 34,600 | 4700 | 1925 | Water Supply, Hydropower |
| 74 | Pit No 6 | Pit River | Pac Gas And Electric Co | 15,700 | 5020 | 1965 | Water Supply, Hydropower |
| 75 | Pit No 7 | Pit River | Pac Gas And Electric Co | 34,000 | 5170 | 1965 | Water Supply, Hydropower |
| 76 | Red Rock No 1 | Red Rock Creek | John Jay Casey | 10,000 | 43.3 | 1893 | |
| 77 | Redinger | San Joaquin River | Southern California Edison Co | 35,000 | 1392 | 1951 | Water Supply, Hydropower |
| 78 | Relief | Summit Creek | Pac Gas And Electric Co | 15,122 | 24.51 | 1910 | |
| 79 | Rollins | Bear River | Nevada Irrigation District | 66,000 | 104 | 1965 | |
| 80 | Salt Springs | Nfk Mokelumne River | Pac Gas And Electric Co | 141,900 | 169 | 1931 | |
| 81 | Salt Springs Valley | Rock Creek | Rock Creek Water District | 10,900 | 20.03 | 1882 | |
| 83 | San Luis | San Luis Creek | US Bureau Of Reclamation | 2,041,000 | 84.6 | 1967 | |
| 84 | Scotts Flat | Deer Creek | Nevada Irrigation District | 49,000 | 20 | 1948 | Water Supply, Hydropower |
| 85 | Shasta | Senator Wash | US Bureau Of Reclamation | 4,552,000 | 6665 | 1945 | Flood Management |
| 86 | Shaver Lake | Stevenson Creek | Southern California Edison Co | 135,283 | 29.3 | 1927 | Water Supply, Hydropower |
| 87 | Slab Creek | Sfk American River | Sacramento Muni Utility Dist | 16,600 | 497 | 1967 | Water Supply, Hydropower |
| 88 | Sly Creek | Lost Creek | Oroville Wyandottie ID | 65,050 | 23.9 | 1924 | Water Supply, Hydropower |
| 89 | Sly Park | Sly Park Creek | US Bureau Of Reclamation | 41,000 | 47 | 1955 | |
| 90 | Stony Gorge | Stoney Creek | US Bureau Of Reclamation | 50,350 | 735 | 1928 | Water Supply |
| 91 | Success | Tule River | USACE | 82,300 | 393 | 1961 | Flood Management |
| 92 | Thermalito Ab | Tr Feather River | DWR | 57,041 | 13.3 | 1967 | |
| 93 | Thermalito Div | Feather River | DWR | 13,328 | 3640 | 1967 | |
| 94 | Thermalito Fb | Tr Cottonwood Creek | DWR | 11,768 | 3.6 | 1967 | |
| 95 | Thomas Edison/Vermilion Valley | Mono Creek | Southern California Edison Co | 125,000 | 90.9 | 1954 | Water Supply, Hydropower |
| 96 | Tule Lake | Cedar Creek | Lyneta Ranches | 39,500 | 82 | 1904 | |
| 97 | Tulloch | Stanislaus River | Oakdale So San Joaquin ID | 68,400 | 971 | 1958 | Hydropower, Flood Management |
| 98 | Turlock Lake | Tr Tuolumne River | Turlock Irrigation District | 45,600 | 10.4 | 1915 | |
| 99 | Union Valley | Silver Creek | Sacramento Muni Utility Dist | 230,000 | 84 | 1963 | Water Supply, Hydropower |
| 100 | Virginia Ranch | Dry Creek | Browns Valley Irrigation Dist | 57,000 | 72.3 | 1963 | |
| 101 | West Valley Reservoir | West Valley Creek | S Fork Irrigation District | 23,000 | 134.8 | 1936 | |
| 102 | Whiskeytown | Clear Creek | US Bureau Of Reclamation | 241,100 | 201 | 1963 | |
| 103 | Wishon | Nfk Kings River | Pac Gas And Electric Co | 118,000 | 177 | 1958 | Water Supply, Hydropower |
| 104 | Woodward | Simmons Creek | South San Joaquin ID | 18,441 | 12 | 1918 | Water Supply, Hydropower |

Notes:

1. Drainage area (DA) in square miles
2. Completion date of dam and beginning of operation (DOB)

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TERMINOLOGY AND BACKGROUND

"Flood damage reduction" is an important water resource function performed by the USACE. The goal of flood damage reduction is to minimize detrimental impacts caused by flows in excess of conveyance capacities of existing drainage systems. This can be accomplished through a variety of structural (i.e., reservoirs and levees) and non-structural measures (i.e., floodplain management policies, early warning systems, and wetland attenuation areas).

The USACE used to refer to flood damage reduction as "flood control." This term was discarded, because extreme floods tend to surpass the design capabilities of management systems and are therefore uncontrollable. Essentially a misnomer, flood control misrepresented the true nature of floods and of the management systems established to cope with flood impacts.

Reservoirs are a key tool in reducing flood damages. The Flood Control Act of 1944 authorized the USACE to prescribe regulations for the use of reservoir storage dedicated to flood damage reduction for all facilities constructed wholly or in part with federal funds (Public Law 534, December 22, 1944, 78th Congress, 2d Session). In the Central Valley, most reservoirs with flood storage space are classified as "Section 7" projects. These are reservoirs owned and operated by agencies other than the USACE. In accordance with the Flood Control Act, the USACE has established operational criteria for the flood space in these projects and is responsible for providing guidance to the reservoir owners and operators regarding proper operational decisions (i.e., flood flow releases) when reservoir storage encroaches space allocated for flood storage. Owners are legally obligated to follow the USACE guidelines. In not doing so, they would incur liability for any resulting damages.

The amount of reservoir space dedicated to flood damage reduction is established in coordination with local concerns (i.e., municipalities, water associations, and irrigation districts). These agencies weigh recreation, environmental, and water supply issues with flood risk, potential damages, and levels of protection. The USACE can recommend options, but the locals make the final decision.

The "level of protection" for a reservoir is defined as the most severe flood inflow that the project can store and pass without violating downstream operation constraints. Each flood damage reduction project has a unique level of protection that is tied to basin-specific operation criteria (i.e., channel capacity below the dam and amount of flood space), flood inflows, flows from downstream tributaries (often referred to as local flows), and regulating effects of upstream reservoirs.

The level of protection (as a function of inflow) is related to the hydrologic record used to characterize the flood frequencies of that basin. Therefore, with each passing year, more information becomes available regarding basin flood dynamics, and the level of protection is continuously redefined. Most years do not significantly affect the level, but large flood years (i.e., 1997) can be very influential, as they provide the most information regarding extreme floods.

The amount of flood space chosen establishes an operational zone within the reservoir. A simplified water control diagram is shown in Plate 3. Flood space is always the top zone, it is kept vacant at all possible times to provide consistent protection for downstream areas and includes all storage available above the "top of conservation." The bottom of the flood pool is typically referred to as the top of conservation. Below this level, the reservoir is in the conservation pool and the reservoir owners and operators determine releases based on storage constraints, release capabilities, and downstream uses including municipal, environmental, hydropower, and agriculture demands. At pool elevations above the top of conservation, the flood space is encroached and the USACE has authority to recommend flood releases. Flood space will continue to fill until outflow from the reservoir exceeds inflow. If all flood space becomes filled, the reservoir reaches "gross pool" and subsequently becomes surcharged. Gross pool usually coincides with the crest of a spillway or the point at which the reservoir must begin to release water in excess of downstream operational limits.

In some cases, part of the required flood space may be offset by available storage at upstream reservoirs. These headwater facilities do not have specific flood damage reduction functions, but still capture a portion of the natural flood flows of the basin. In this sense, the space available upstream acts as flood space and the top of conservation at the downstream flood damage reduction reservoir can be increased (decreasing the flood space) proportionally. These scenarios can provide water supply benefits without lowering the level of protection for downstream areas and are typically referred to as "credit space" agreements.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# CHAPTER III

# BASELINE HEC-5 METHODOLOGY

## GENERAL

Reservoirs were selected for inclusion in the study based on two criteria: 1) their existing flood damage reduction functions; or 2) they maintain an active storage greater that 10,000 acre-feet and regulate a significant natural drainage area. All reservoirs over 10,000 acre-feet are shown for the Sacramento and San Joaquin river basins in Plates 1 and 2, respectively. The majority of facilities modeled do not have formal flood damage reduction responsibilities, but still alter the form and timing of flood hydrographs. The influence of non-flood damage reduction reservoirs is significant and cannot be ignored in a holistic watershed study.

Simulation models were developed for both the Sacramento and San Joaquin river basins. Due to the number of facilities and control points, these models were further split into headwater models and lower basin models leading to a total of 4 separate HEC-5 models: 1) Sacramento headwaters; 2) Sacramento lower basin; 3) San Joaquin headwaters; and 4) San Joaquin lower basin. The headwater model for each basin generally contains reservoirs located upstream of flood damage reduction projects. Lower basin models contain those flood projects as well as a few water supply, recreation, and hydropower facilities.

HEC-5 routes flows through reservoirs based on operational criteria provided by the modeler. Although HEC-5 is capable of performing period of record simulations, criteria currently focus on operations for flood damage reduction reservoirs that are encroached and general winter operations for water supply and hydropower reservoirs.

All models perform hourly flood simulations using the 30-day hourly hydrographs, detailed within Appendix B – Synthetic Hydrology, as source data for all seven reservoir inflow synthetic exceedence frequencies. The synthetic hydrology investigated flood frequencies at mainstem and tributary locations. Storm centerings were then formulated and analyzed. For each centering, synthetic natural flow hydrographs were computed at locations throughout the Central Valley as tabulated in Attachment B.4 – Synthetic Flood Centerings. Typically, each tributary basin contained one hydrograph location. Many of these sites were inflow points to major flood management projects (i.e., Feather River at Oroville Dam). These natural flow hydrographs represent flood time series produced by a wholly unimpaired drainage area; hydrographs do not reflect the influence of headwater reservoirs.

A 3-step process was required to analyze each storm centering as shown in Plate 6. To begin the sequence, the headwaters models were simulated. Then, using the resulting storage time series for select headwater facilities, top of conservation storage for those flood damage reduction projects with established credit space agreements were computed. Next, using the results of the headwater simulations and the computed top of conservation series, the lower basin models were simulated, thereby completing the procedure.

Full basin simulations were run for each centering regardless of storm location or intensity.

## HEADWATER RESERVOIRS

Headwater reservoirs are typically located in the watersheds above flood damage reduction projects. Primarily used for water supply and hydropower generation, these facilities do not have any type of formalized flood operations. A total of 44 headwater reservoirs (27 in the Sacramento and 17 in the San Joaquin) were modeled. Selected headwater reservoirs are shown in Table III-1.

### Operational Criteria

Headwater reservoirs do not have published criteria to guide modelers. In this study, criteria were developed through conference calls with facility owners and operators as shown in Table III-1, and analysis of gage data collected and processed by the Water Management Section in Phase I and II of the Comprehensive Study. Whenever possible, operations discussed during the phone interviews were confirmed with gage data. When discrepancies were discovered, follow-up calls were made to clarify historic operations, and final criteria were established in accordance with both the expert commentary and historic records.

Operations were generally less complex than those required to model flood damage reduction projects. Most focused on some type of constant release philosophy. Water supply reservoirs often released only the minimum flows required to satisfy instream requirements for fish and wildlife. These reservoirs are referred to as “fill and spill,” because pools are operated to capture as much water as possible, usually filling up to and above spillway crest during a strong rainfall event. Hydropower facilities typically began to release flows to generate maximum power whenever a spill was imminent. To these facilities, any flow over the spillway represents lost revenue because it has not been routed through power generation penstocks.

### Physical Characteristics

Elevation-capacity tables, outlet and spillway ratings, and facility schematics were obtained from the California State Division of Safety of Dams (DSOD). When data were not available at DSOD, reservoir owners were contacted. All agencies responded to the data requests. A few of the agencies that deserve special recognition for providing large amounts information are Pacific Gas and Electric, Southern California Edison, and U.S. Bureau of Reclamation.

### Preparing Model Input

Prior to simulation of headwater reservoirs, flows needed to be split from the single natural flow series at the frequency curve location into inflow hydrographs at all upstream reservoirs as shown in Table III-2. This was performed on a tributary specific basis. For example, the natural hydrograph for Feather River at Oroville Dam was split into 10 parts (8 hydrographs to reflect natural inflows to headwater reservoirs and 2 hydrographs to reflect the contribution of unregulated watershed area between reservoirs in series).

## TABLE III-1

## HEADWATER RESERVOIR OPERATIONS

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| ***Sacramento River Basin*** | | | |
| **Antelope**<br>Owner: DWR<br>(Feather River) | Min flow = 5 cfs<br>Max outlet flow = 150 cfs<br>(30" pipeline) | Fill and spill reservoir. Reservoir will release minimum flow until spill. Spills during a normal year. | Release minimum flow till and during spill. |
| **Butt Valley**<br>Owner: Pacific Gas and Electric<br>(Feather River) | Max (combined) flow to the powerhouses = 2,500 cfs | In addition to natural inflows, Butt Valley receives power releases from Lake Almanor. Butt Valley has a minimum winter pool of 34,000 to 35,000 ac-ft. Butt Valley generates power through two plants, which have a combined power flow of 2,500 cfs. | Release half of the maximum power flow between minimum pool and 39,000 ac-ft. Above this storage, release full maximum power flow. |
| **Bucks Storage**<br>Owner: Pacific Gas and Electric<br>(Feather River) | Min flow = 1 cfs<br>Max power flow = 395 cfs | Bucks Storage has a target pool of 45,000 ac-ft that PGE tries to reach by December 31. Generally, Bucks is shut down during rainfall events and downstream generation is supplied by natural flows from Grizzly Creek. If the pool gets high, power releases will be made to the Grizzly powerhouse and flows will be spilled from Grizzly Forebay and out of the generation system. | Release maximum power and minimum flows till and during spill. |
| **Bowman**<br>Owner: Nevada Irrigation District<br>(Yuba River) | Min flow = 3.5 cfs<br>Max outlet flow = 375 cfs<br>(2 outlets, one powerhouse penstock, one canal outlet) | Operated first for water supply. Gated spillway used to capture additional storage near the end of the wet season (gate operations are related to snowpack runoff). During flood season, gates remain full open. | Gage record indicates outlet releases in excess of minimum flow prior to spill in 1997 and 1986. Ramp up to max outlet as pool rises. Divert first 250 cfs in excess of minimum flow to Spaulding Reservoir. |
| **Camp Far West**<br>Owner: South Sutter Irrigation District<br>(Bear River) | | Low flow gage record indicates fish flow releases of between 12 and 18 cfs in December 1996. | Release 15 cfs (typical winter release) till and during spill. |
| **East Park**<br>Owner: USBR<br>(Stony Creek) | Max flow = 750 cfs<br>Min pool = 5,000 ac-ft<br>Min flow = 5 cfs | Fill and spill reservoir. Reservoir used only for water supply. No hydropower. In winter months, reservoir will release minimum flow until spill. | Release minimum flow till and during spill. |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

## TABLE III-1 (CONT.)

## HEADWATER RESERVOIR OPERATIONS

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Fordyce**<br>Owner: Pacific Gas and Electric<br>(Yuba River) | Min flow = 5 cfs<br>(Fordyce) | Fordyce is higher in elevation and has a smaller drainage area than Spaulding and therefore tends to spill less often and with smaller magnitude. Fordyce has a target pool of 4,000 to 5,000 ac-ft that is usually reached by January 1. After this, it is mainly in a storage mode. If the pool gets high, Fordyce will feed waters to Spaulding to support generation once Spaulding inflows have receded and the pool comes under control. | Release minimum flow until spill. |
| **French Meadows - LL Anderson**<br>Owner: Placer County Water Agency<br>(American River) | Min flow = 8 cfs<br>Max power flow = 400 cfs | French Meadows generates power via the French Meadows Powerhouse. Power generation in unimpaired by spill at either reservoir. Spill from French Meadows creates sedimentation problems at downstream structures, but pre-releases from French Meadows are usually not made. Releases typically hold at max power in hopes that inflows will recede. | Release maximum power and minimum flow (408 cfs) till and during spill. Divert first 400 cfs in excess of minimum flow to Hell Hole Reservoir. |
| **Frenchman**<br>Owner: DWR<br>(Feather River) | Min flow = 2 cfs<br>Max outlet flow = 160 cfs<br>(36" pipeline) | Will release flows through the outlet works to minimize spill from the dam, which is potentially damaging to downstream distribution systems. Outlet works are head dependent. 160 cfs can be released at full lake (5,588-ft). Spills during a normal year. | Release maximum outlet when filled higher than 90 percent of capacity. |
| **Hell Hole**<br>Owner: Placer County Water Agency<br>(American River) | Min flows = 10 cfs<br>(December 15 – May 14)<br>Max power flow = 1,000 cfs | In the fall and early winter months, PCWA reduces storage in Hell Hole and French Meadows to 140,000 to 150,000 ac-ft. Of this total, 90,000 to 100,000 ac-ft is typically stored in Hell Hole. Pools are further lowered preceding the snowmelt, which usually tops off the pools in June. Hell Hole generates power via the Middle Fork Powerhouse and will do so while spilling. | Release maximum power and minimum flow (1,010 cfs) till and during spill. |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

## TABLE III-1 (CONT.)

## HEADWATER RESERVOIR OPERATIONS

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Ice House**<br>Owner: Sacramento Municipal Utility District<br>(American River) | Min flow = 3 cfs<br>(January 1 – April 30)<br>Max power flow = 285 cfs (via Jones Fork Powerhouse to Union Valley)<br>Max outlet flow = 700 cfs (hollow cone valve) | During wet periods, reservoir will release maximum power flows through Jones Fork Powerhouse into Union Valley Reservoir till and during spill. | Release maximum power and minimum flows (288 cfs). Divert first 285 cfs in excess of minimum flow to Union Valley Reservoir. |
| **Jackson Meadows**<br>Owner: Nevada Irrigation District<br>(Yuba River) | Min flow = 5 cfs<br>Max outlet flow = 400 cfs (flow to a canal could add an additional 20 cfs) | Operated first for water supply. Gated spillway used to capture additional storage near the end of the wet season (gate operations are related to snowpack runoff). During flood season, gates remain full open. | Gage record does not indicate high outflows during flood periods. Release 35 cfs (typical release during 1997 and 1986 floods) until and during spill. |
| **Lake Almanor**<br>Owner: Pacific Gas and Electric<br>(Feather River) | Min flow = 35 cfs<br>Max power flow = 2,118 cfs<br>Max outlet flow = 2,200 cfs | Generally, Almanor tends to store inflows until basin flows recede. This allows both the basin flows and then the Almanor releases to be routed through system powerhouses. However, if the reservoir fills high enough, power releases will be made through powerhouses high in the basin and sacrificed in the lower system where flows are already more than sufficient to satisfy power generation requirements. Almanor has a maximum pool of 1,100,000 ac-ft. Almanor will go to full outlet in addition to max power to stay below maximum pool (as seen in 1997). If the outlet is opened to maintain storage below maximum pool, it is opened fully. | Release minimum flow throughout simulations. In addition, ramp up to and hold maximum power releases until storage exceeds 943,000 ac-ft. Above this storage, release maximum outlet and maximum power flows. |
| **Lake Davis - Grizzly Valley**<br>Owner: DWR<br>(Feather River) | Min flow = 10 cfs<br>Max outlet flow = 210 cfs (two outlets: 10" and 30" pipelines) | Will try to avoid spilling by pre-releasing through the outlet works. Outlet works are head dependent. 210 cfs can be released at full lake (5,775-ft). | Release max outlet when filled higher than 70 percent of capacity. |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

## TABLE III-1 (CONT.)

## HEADWATER RESERVOIR OPERATIONS

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Little Grass Valley**<br>Owner: Oroville Wyandotte Irrigation District (Feather River) | Max outlet flow = 600 cfs<br>Min flow = 5 cfs<br>(November 1 – April 30) | Reservoir is water supply only, no hydropower. In the winter months, reservoir will release minimum flow until spill. | Release 5 cfs (minimum flow) till and during spill. Divert first 225 cfs in excess of minimum flow to Sly Creek Reservoir. |
| **Loon Lake**<br>Owner: Sacramento Municipal Utility District (American River) | Min flow = 8 cfs<br>Max power flow = 700 cfs (approximate value based on gage records) | Loon Lake releases can be routed to Union Valley through a diversion on the South Fork of the Rubicon River. Power flows are usually lowered when flows on the South Fork are high. Average power flows during flood periods in 1995 and 1997 were well below maximum capacity. | Release typical power flows (150 cfs; as recorded during the 1995 and 1997 flood events) and minimum flow till and during spill. |
| **McCloud**<br>Owner: Pacific Gas and Electric<br>(Sacramento River above Shasta) | Min flow = 40 cfs (December 1 – April 30)<br>Diversion flow = 1,000 cfs to 1,400 cfs (related to the head differential between McCloud and Iron Canyon) | During the winter months in wet years, McCloud is pulled down to 18,000 ac-ft. As McCloud fills, water is diverted to Black Powerhouse (through Iron Canyon Reservoir). This water enters the Pit River above Pit #6. | Release maximum average flow directly to Black Powerhouse (1,200 cfs) and minimum flow to McCloud River (40 cfs). Neglect influence of Iron Canyon Reservoir. |
| **Merle Collins**<br>Owner: Browns Valley Irrigation District<br>(Dry Creek – Yuba Drainage) | Min flow = 2.5 cfs (at Smith Diversion)<br>Max power flow = 100 cfs | Operated first for water supply. Hydropower will be generated at high pool elevations and while spilling. Typical water supply operations pull the pool to about 5,000 to 6,000 ac-ft after the irrigation season. Reservoir usually fills by mid-January in average to above average water year. | Release minimum flow until storage exceeds 55,000 ac-ft. Then begin to release maximum power flows. |
| **Mountain Meadows**<br>Owner: Pacific Gas and Electric<br>(Feather River) | Max power flow = 200 cfs | Mountain Meadows has a wintertime maximum storage of less than 5,000 ac-ft. PGE maintains an operational storage of 3,000 to 5,000 ac-ft and will empty additional storage as quickly as possible. Max power is 200 cfs and is unaffected by spillway flows. | Release maximum power till and during spill. |
| **Pit #3 (Lake Britton)**<br>Owner: Pacific Gas and Electric<br>(Sacramento River above Shasta) | Min flow = 150 cfs<br>Min pool = 26,852 ac-ft<br>Max pool = 40,626 ac-ft<br>Max power flow = 3,315 cfs<br>Max outlet flow = 7,500 cfs | Whenever possible, reservoir storage is maintained below 40,626 ac-ft to prevent erosion at a recreational beach. Based on a wet forecast, Lake Britton may increase power releases and reduce storage to around 33,000 to 35,000 ac-ft. | Release maximum power and minimum flows until storage 39,200 ac-ft. Above this level, transition to maximum power and full outlet releases (10,815 cfs). |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

# TABLE III-1 (CONT.)

## HEADWATER RESERVOIR OPERATIONS

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Pit #6 and Pit #7**<br>Owner: Pacific Gas and Electric<br>(Sacramento River above Shasta) | Min flow = 150 cfs (Pit #7)<br>Max power flow = 6,470 cfs (Pit #6)<br>Max power flow = 7,440 cfs (Pit #7) | Pit #6 and #7 are operated near full year round. Based on a wet forecast, reservoirs may be pulled down to minimum pools of 30,000 ac-ft at Pit #7 and 13,000 ac-ft at Pit #6. Both facilities release either maximum power or minimum flow and have no problems with generation while spilling. | Release maximum power from Pit #6 till and during spill. Release maximum power and minimum flow from Pit #7 till and during spill. |
| **Rollins**<br>Owner: Nevada Irrigation District<br>(Bear River) | Min flow = 20 cfs<br>Max outlet flow = 900 cfs (2 outlets, Bear River Canal and one to the Bear River) | Flows released from Rollins can be diverted to the American River Basin through the Bear River Canal, which feeds multiple power generation facilities. Rollins typically spills in above average water years. | Release maximum outlet flow till and during spill. Divert first 310 cfs in excess of minimum flow to American River Basin. |
| **Scotts Flat**<br>Owner: Nevada Irrigation District<br>(Deer Creek – Yuba Drainage) | Min flow = none<br>Max outlet flow = 180 cfs (92 cfs via power conduit and 88 cfs via power bypass) | Operations are driven by water supply with a goal of reaching full lake by April 1 of each year. Lake typically fills in February or March in average to above average years. During wet times and while reservoir is spilling, max power will be released, but power will always be sacrificed to protect or ensure water supply. | Release maximum power flow till and during spill when filled higher than 85 percent of capacity. |
| **Sly Creek**<br>Owner: Oroville Wyandotte Irrigation District (Feather River) | Min flow = none<br>Max power = 850 cfs | During wet years, Sly Creek will release maximum power regardless of spill. There is a downstream minimum flow requirement at Lost Creek Diversion Dam, but this is met by natural flows from Lost Creek. | Release 850 cfs (maximum power release) till and during spill. |
| **Spaulding**<br>Owner: Pacific Gas and Electric<br>(Yuba River) | Min flow = 5 cfs (Spaulding) | In addition to natural inflows, Spaulding receives Fordyce releases and diversion flows through the Bowman-Spaulding Canal. Spaulding has a target pool of 20,000 to 25,000 ac-ft. The pool may be pulled below this based on a large snowmelt runoff. Spaulding generates power via canals that carry water primarily to the Bear River drainage. | Release approximate historic (1986, 1995 and 1997 flood events) power releases and minimum flow until storage exceeds 50,000 ac-ft. Above this level, increase river outlet flows to 100 cfs. Divert first 600 cfs in excess of minimum flow to Bear drainage above Rollins. |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

## TABLE III-1 (CONT.)
## HEADWATER RESERVOIR OPERATIONS

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Stony Gorge**<br>Owner: USBR<br>(Stony Creek) | Min pool = 7,500 ac-ft<br>Min flow = 5 cfs<br>(Seepage roughly 15 cfs) | Fill and spill reservoir. Reservoir used only for water supply. No hydropower. In winter months, reservoir will release minimum flow until spill. Seepage at the dam exceeds minimum flow requirements. | Release 15 cfs (seepage) till and during spill. |
| **Union Valley**<br>Owner: Sacramento Municipal Utility District<br>(American River) | Min flow = 0 cfs<br>Max power flow = 1,500 cfs<br>(approximate value) | In addition to natural inflows, Union Valley receives flows from Ice House reservoir (via Jones Fork Powerhouse) and the Rubicon River (via the diversion to Robbs Peak Powerhouse). During wet periods, Union Valley will release maximum power flows through Union Valley Powerhouse till and during spill. | According to gage records, average power releases during the 1995 and 1997 flood events did not maintain maximum release levels throughout the flood period. Model with a 1,000 cfs power release. |
| ***SAN JOAQUIN RIVER BASIN*** | | | |
| **Bass Lake/Crane Valley**<br>Owner: Pacific Gas and Electric<br>(San Joaquin above Friant) | Min flow = none<br>Max power flow = 140 cfs<br>(reduced from 160 cfs for channel integrity) | Usually kept close to full after snowmelt during the spring and summer (within 3,000 ac-ft of capacity). After the summer months, the pool is drawn down slightly. Storage usually hovers near 25,000 to 26,000 ac-ft throughout the winter. Max power releases are limited by downstream channel integrity concerns. | Release maximum power flow (140 cfs) at storage above 25,000 ac-ft till and during spill. |
| **Beardsley and Donnells**<br>Owner: Oakdale South San Joaquin Irrigation District<br>(Stanislas River) | Donnells:<br>Min flow = 16 cfs<br>Max power flow = 750 cfs<br>Min pool = 5,000 ac-ft<br>Beardsley:<br>Min flow = 50 cfs<br>Max power flow = 600 cfs<br>Min pool = 20,000 ac-ft | Both reservoirs generally release maximum power flows up to and above the spillway crest. Pools are lowered in the fall and winter months. Minimum pool limits are usually reached in February or March. | Release maximum power and minimum flows from both facilities (766 cfs from Beardsley and 650 cfs from Donnells). |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

**TABLE III-1 (CONT.)**

**HEADWATER RESERVOIR OPERATIONS**

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Cherry Valley**<br>Owner: City and County of San Francisco (CCSF)<br>(Tuolumne River) | Min flow = 5 cfs<br>(October 1 – June 30)<br>Max power flow = 950 cfs | All of these CCSF reservoirs are operated first for water supply. In addition to natural inflows, Cherry Valley receives flow from Lake Eleanor via the Cherry-Eleanor Tunnel. Cherry Valley has three operational flow levels above minimum flow. The first is maximum power releases to Holm Powerhouse. The second is the highest release that does not effect power generation efficiency (6,000 cfs) and the final level is the highest flow that can pass through downstream areas without causing damages (28,000 cfs). CCSF will make releases to keep potential flows within these levels. | Operate Cherry Valley for conditions at Holm Powerhouse. When flows are below 5,000 cfs release maximum power and minimum flow (955 cfs) until storage exceeds 90 percent of capacity. Above this storage, ramp up releases as much as possible while maintaining flows below 6,000 cfs at Holm Powerhouse. |
| **Courtright**<br>Owner: Pacific Gas and Electric (PG&E)<br>(Kings River) | Min flow = 2.5 cfs<br>(December 1 – May 31) | Courtright and Wishon are located in series, high in the Kings River watershed (higher than 6,500-ft above sea level). Supply is derived primarily from snowmelt. Reservoirs are pulled down in the winter to make space for the melt. The normal minimum combined pool is 60,000 ac-ft (the actual minimum operational storage at Courtright is 5,000 ac-ft).. | Model Courtright and Wishon as a single reservoir. Combine storage and inflows. Use the outlet works of Wishon as those of the composite reservoir. Refer to Wishon HEC-5 modeling for more information. |
| **Edison**<br>Owner: Southern California Edison Company (SCE)<br>(San Joaquin River above Friant) | Min flows = 7.5 cfs<br>(November 1 – April 30) | SCE reduces storage in the fall to a minimum pool that is based on snowpack forecasts. SCE releases to meet minimum pool by early spring and will go as low as 6,000 ac-ft during wet years. Storage is reduced at a rate of up to 450 cfs per day. Most of this water is diverted to the Bear-Mono Conduit and onto the Ward Tunnel, which transports flow to Huntington Reservoir. During high waters, diversions to the Bear-Mono Conduit may be shut off. If Edison is high and cannot offset inflow with a 450 cfs release, outflows may be increased. Any releases above 450 cfs flow past the diversion works and on to Mammoth Pool. | Release minimum flow until storage exceeds 120,000 ac-ft. Above this storage, increase releases to full outlet (1,700 cfs). |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

**TABLE III-1 (CONT.)**

**HEADWATER RESERVOIR OPERATIONS**

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Florence**<br>Owner: Southern California Edison Company<br>(San Joaquin River above Friant) | Min flow = 15 cfs (November 1 – April 30) | Florence is almost entirely emptied by November 1 of each year; SCE usually pulls the pool down to 1,200 ac-ft. Storage accumulated in Florence from rain events is routed through Ward Tunnel to Huntington and Shaver as soon as there is sufficient space in those pools. SCE tries to keep flows below the dam less than 3,000 cfs. Florence has a gated spillway with no seasonal restrictions and uses the final 11,000 ac-ft of available storage to minimize spill, but water has never been this high during the winter. Gaged maximum flow to Ward Tunnel is 1,770 cfs, but winter flows rarely exceed 1,000 cfs and are usually held below 200 cfs. | Release minimum flow until storage exceeds 60,000 ac-ft. At this level, increase flows to 3,000 cfs. |
| **Hetch Hetchy**<br>Owner: City and County of San Francisco<br>(Tuolumne River) | Min flows = 50 cfs (January 1 – January 31; while drafting more than 920 cfs, min flow required is increased by 64 cfs)<br>Max power flow = 1,350 cfs | Hetch Hetchy is an important water source for the City of San Francisco. Water is delivered to the City through the Hetch Hetchy Aqueduct. During periods of high flows, waters become turbid and CCSF limits flows through the aqueduct to approximately 110 cfs. Hetch Hetchy has three operational flow levels above minimum flow. The first is maximum power (1,350 cfs). The second is the highest release that does not effect power generation efficiency (7,000 cfs) and the final level is the highest flow that can pass through downstream areas without causing damages (18,000 cfs). CCSF will make releases to keep potential spills within these levels. | Release maximum power and minimum flow (approximately 1,500 cfs) until storage exceeds 90 percent of capacity. Above this storage, ramp up releases and hold at 7,000 cfs. If storage exceeds 95 percent of capacity, increase releases to maximum outlet (approximately 15,000 cfs). Aqueduct diversion is held constant at 110 cfs. |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

**TABLE III-1 (CONT.)**

**HEADWATER RESERVOIR OPERATIONS**

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Huntington**<br>Owner: Southern California Edison Company<br>(San Joaquin River above Friant) | Min flow = 2 cfs | Maintained consistently at a high pool (1,000 ac-ft below capacity) during summer months. After Labor Day, storage is reduced to 30,000 ac-ft by early spring. During this drawdown, a power flow (300 cfs) is typically routed through Big Creek Powerhouse #1 and on to Redinger. An additional 200 cfs is normally diverted from Huntington to Shaver through Balsam Forebay. This 500 cfs pull is usually half offset by natural inflow and diversion flows through the Ward Tunnel. A large percentage of Huntington inflow is diverted from Florence and Edison Reservoirs through the Ward Tunnel. SCE prevents any spill from Huntington Reservoir. If the pool gets high, Ward Tunnel flows will be reduced or shut off. Huntington has gated spillways with SCE self-imposed restrictions because of downstream domestic water contamination concerns. | Release 500 cfs. Ward Tunnel is not modeled based on information that indicated flows can be cut back when Huntington inflows and storage are high. |
| **Lake Eleanor**<br>Owner: City and County of San Francisco<br>(Tuolumne River) | Min flow = 5 cfs (November 1 – February 28 and while diverting to Cherry Valley) | Lake Eleanor is the smallest of the three CCSF reservoirs in the Tuolumne headwaters. Eleanor is connected to Cherry Valley Reservoir via the Cherry-Eleanor Tunnel. The tunnel has a maximum conveyance of 500 cfs obtainable at variable pool elevations through stage or pump driven flows. Flows will not be diverted while Cherry Valley is spilling, but may be used when Eleanor is closer to full capacity than Cherry Valley. | Release maximum flow to the tunnel and minimum flow (505 cfs) till and during spill. Divert first 500 cfs in excess of minimum flow to Cherry Valley Reservoir. |
| **Lower Bear**<br>Owner: Pacific Gas and Electric<br>(Mokelumne River) | Min flow = 2 cfs (November 1 – April 30)<br>Max power flow = 218 cfs | Lower Bear generates power via Salt Springs Powerhouse #2. Flows to the powerhouse can be diverted from Cole Creek or released from Lower Bear. Lower Bear usually tops off during the spring runoff and will begin to make power releases when Cole Creek recedes. Power generation is unaffected by spillway flows. | Release maximum power and minimum flow (220 cfs) till and during spill. |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

## TABLE III-1 (CONT.)
## HEADWATER RESERVOIR OPERATIONS

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Mammoth**<br>Owner: Southern California Edison Company<br>(San Joaquin River above Friant) | Min flow = 10 cfs<br>(November 1 – April 15) | Mammoth storage is reduced from its summer pool to general targets of 35,000 ac-ft by January 1 and 10,000 ac-ft by March 1. Mammoth has an ungated spillway and will release max power (2,420 cfs) to lower storage and during spilling. | Release maximum power and minimum flow when storage is in excess of 11,000 ac-ft. Maintain maximum power flow during spill. |
| **New Spicer Meadows**<br>Owner: Calaveras County Water District<br>(Stanislas River) | Min flow = 16.5 cfs<br>Max outlet flow = 2,000 cfs | Power generation at New Spicer Meadows (NSM) is typically shut down during the winter months. NSM has enough capacity to store most natural inflow. Generation at downstream projects is primarily fed by natural flow (runoff below NSM) during winter months. Releases pick up in May or June when downstream facilities can utilize released flows. Maximum power release is 350 to 400 cfs. | In accordance with gage records for the 1997, 1986, and 1995 flood seasons, release maximum power flow (350 cfs) at storage above 55 percent of capacity. |
| **Redinger**<br>Owner: Southern California Edison Company<br>(San Joaquin River above Friant) | Min flow = 3 cfs<br>(below dam)<br>Min flow = 20 cfs<br>(below Willow Creek) | Maintained near full pool throughout the year. Maximum power through Big Creek Powerhouse #4 is 3,600 cfs and generation is head-dependent. The spillway at Redinger has 4 radial gates that can be operated year-round. | Release maximum power and minimum flow (3,620 cfs) when storage is in excess of 20,000 ac-ft. Model spillway without gates with a gross pool of 25,000 ac-ft. Develop rating curve based on gate releases made during the 1997 flood event. |
| **Salt Springs**<br>Owner: Pacific Gas and Electric<br>(Mokelumne River) | Min flow = 20 cfs<br>(November 1 – April 30)<br>Max power flow = 600 cfs | The reservoir typically fills and spills by the end of May and can continue to spill into July during wet years. Max power flow is 600 cfs and generation is unaffected by spill. Both Salt Springs and Lower Bear tend to spill in average to above average years. | Release maximum power till and during spill. |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

**TABLE III-1 (CONT.)**

**HEADWATER RESERVOIR OPERATIONS**

| Reservoir, Owner [a] | Data | Operations Information [b] | HEC-5 Modeling |
|---|---|---|---|
| **Sly Park - Jenkinson Lake**<br>Owner: U.S. Bureau of Reclamation<br>(Cosumnes River) | Min flow = 1 cfs<br>Max outlet flow = 125 cfs | Reservoir supplies flow to a water treatment plant, which provides drinking water to the Eastern Slope of Eldorado County. Typical flows are approximately 10 to 15 cfs during winter months. Sly Park spills in nearly all water years. Treatment plant releases are maintained during times of spill. | Release minimum and typical treatment plant flows (total of 15 cfs) till and during spill. |
| **Shaver**<br>Owner: Southern California Edison Company<br>(San Joaquin River above Friant) | Min flow = 3 cfs | During wet years, the minimum summer pool (June 15 - September 1) in Shaver is 90,000 ac-ft. Storage is reduced in the fall and winter to a general target of 76,000 ac-ft by February 1. During this pull down, typically Shaver releases 300 cfs to Big Creek Powerhouse #2a, which then flows on to Redinger. As with Huntington, SCE does not spill Shaver. Shaver has a small natural watershed and a high percentage of inflow is delivered through diversions. SCE operates Shaver to prevent any possibility of spill. | To simplify simulations, the Huntington to Shaver diversion was not modeled. Instead, model releases were reduced from SCE's typical power release of 300 cfs to 100 cfs. This adjusted for the 200 cfs flow that would have been delivered by the diversion. Release 100 cfs flow throughout simulation. |
| **Wishon**<br>Owner: Pacific Gas and Electric<br>(Kings River) | Min flow = 33 cfs<br>(65 ac-ft per day)<br>Max power flow = 850 cfs | The minimum operation pool at Wishon is 33,000 ac-ft. There is a pump-back system between Wishon and Courtright capable of sending high flows upslope. During rainfloods, most likely would pump from Wishon to Courtright to avoid spilling at Wishon. | Release Wishon maximum power and minimum flow from composite reservoir (883 cfs). |

a) Tributary basin is indicated in parentheses below owner.

b) Operations information was obtained through communications between the Water Management Section, Sacramento District, USACE, and the owners and operators of the headwater reservoirs. While some information is based in fact (i.e., minimum flow and pool restrictions), the operation policies are intended to be generic and may not reflect operations during actual floods. Owners and operators manage reservoirs continuously and, to an extent, the character of an individual flood will dictate releases.

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# TABLE III-2

# HEADWATERS MODELING INFORMATION TABLE

| Sacramento River Basin | | | | | |
|---|---|---|---|---|---|
| **River** | **Destination** | **Flow Locations** | **Starting Storage (ac-ft)** | **Travel Time (hours)** | **% Split** |
| American River | Folsom Lake | French Meadows Reservoir | 67,100 | 5[a] | 3[b] |
| | | Hell Hole Reservoir | 130,900 | 6 | 4 |
| | | Loon Lake | 41,100 | 6 | 1 |
| | | Union Valley Reservoir | 199,300 | 5 | 5 |
| | | Ice House Reservoir | 25,400 | 6 | 1 |
| | | Folsom Lake | 530,000 | | 86 |
| Bear River | Near Wheatland | Camp Far West Reservoir | 100,000 | 2 | 62 |
| | | Rollins Reservoir | 65,500 | 7 | 36 |
| | | Near Wheatland | | | 2 |
| Deer Creek | Near Smartsville | Scotts Flat Reservoir | 48,000 | 2 | 30 |
| | | Near Smartsville | | | 70 |
| Dry Creek | Near Yuba | Merle Collins Reservoir | 51,300 | 1 | 85 |
| | | Near Yuba | | | 15 |
| Feather River | Lake Oroville | Little Grass | 70,000 | 2 | 2 |
| | | Sly Creek Reservoir | 50,000 | 1 | 2 |
| | | Frenchman Lake | 40,000 | 6 | 1 |
| | | Lake Davis | 55,000 | 4 | 1 |
| | | Mountain Meadows Reservoir | 4,465 | 5 | 1 |
| | | Lake Almanor | 850,000 | 4 | 8 |
| | | Antelope Lake | 20,000 | 7 | 1 |
| | | Butt Valley Reservoir | 39,500 | 4 | 2 |
| | | Bucks Lake | 60,000 | 2 | 2 |
| | | Lake Oroville | 2,788,000 | | 80 |
| Sacramento River | Lake Shasta | Lake Britton | 32,000 | 6 | 42 |
| | | Pit No. 6 | 14,500 | 2 | 10 |
| | | Pit No. 7 | 30,000 | 1 | 5 |
| | | McCloud Reservoir | 24,000 | 3 | 13 |
| | | Lake Shasta | 3,252,100 | | 30 |
| Stony Creek | Black Butte | East Park Reservoir | 48,210 | 6 | 15 |
| | | Stony Gorge Reservoir | 31,940 | 4 | 30 |
| | | Black Butte Reservoir | 6,702 | | 55 |
| Yuba River | Middle Fork-South Fork | Jackson Meadows Reservoir | 38,000 | 3 | 5 |
| | | Bowman Lake | 40,000 | 3 | 5 |
| | | Fordyce Creek | 16,000 | 3 | 5 |
| | | Spaulding Lake | 40,000 | 2 | 25 |
| | | Middle South Fork | | | 60 |

[a] The travel time between French Meadows Reservoir and Folsom Lake is 5 hours.
[b] The percent split of Folsom Lake's full natural flow attributed to French Meadows Reservoir is 3%.

# TABLE III-2 (CONT.)
# HEADWATERS MODELING INFORMATION TABLE

| San Joaquin River Basin | | | | | |
|---|---|---|---|---|---|
| River | Destination | Flow Locations | Starting Storage (ac-ft) | Travel Time (hours) | % Split |
| Cosumnes River | At Michigan Bar | Sly Park (Jenkinson Lake) | 34,000 | 6 | 9 |
| | | At Michigan Bar | | | 91 |
| Kings River | Pine Flat Reservoir | Courtright-Wishon Reservoir | 100,000 | 2 | 10 |
| | | Pine Flat Reservoir | 525,000 | | 90 |
| Mokelumne River | Camanche Reservoir | Lower Bear River Reservoir | 20,000 | 6 | 5 |
| | | Salt Springs Reservoir | 40,000 | 6 | 27 |
| | | Pardee Reservoir | 200,000 | | 61 |
| | | Camanche Reservoir | 230,900 | | 7 |
| San Joaquin River | Friant/Millerton Lake | Thomas A. Edison Lake | 70,000 | 5 | 3 |
| | | Florence Lake | 1,200 | 6 | 7 |
| | | Huntington Lake | 50,000 | 2 | 5 |
| | | Shaver Lake | 90,000 | 1 | 3 |
| | | Redinger Lake | 20,000 | 1 | 16 |
| | | Mammoth Pool Reservoir | 24,000 | 3 | 38 |
| | | Bass Lake | 25,000 | 3 | 3 |
| | | Friant/Millerton Lake | 350,500 | | 25 |
| Stanislaus River | New Melones Reservior | Beardsley Lake | 50,000 | 6 | 11 |
| | | Donnells Reservoir | 20,000 | 7 | 14 |
| | | New Spicer Meadows Reservoir | 80,000 | 7 | 05 |
| | | New Melones Reservoir | 1,969,504 | | 70 |
| Tuolumne River | Don Pedro Reservoir | Hetch Hetchy Reservoir | 280,000 | 4 | 20 |
| | | Cherry Valley Lake | 180,000 | 4 | 12 |
| | | Lake Eleanor | 15,000 | 4 | 8 |
| | | Don Pedro Reservoir | 1,690,000 | | 60 |

[a] The travel time between French Meadows Reservoir and Folsom Lake is 5 hours.
[b] The percent split of Folsom Lake's full natural flow attributed to French Meadows Reservoir is 3%.

These flow splits were performed by multiplying the full natural hydrograph by a constant percentage based on drainage area ratios, normal annual precipitation (NAP) distribution within the tributary basin, and volume comparisons of flood volume yields at the headwater reservoir and at the full natural flow location. In some instances, the volume comparison was not possible due to a lack of data and the ratio was based solely on NAP distribution and drainage areas.

## River Routings

As the pattern of each full natural hydrograph is an actual flood wave that has occurred in the past, the shape and timing of the hydrograph reflects basin alignment, drainage area, time of concentration, and a multitude of other hydrologic and geomorphic characteristics of the basin. Since the pattern is a function of the basin, headwater simulations must take care not to introduce undue influences. For instance, the shape of the full natural flow hydrograph already contains travel times and routing effects of individual forks of the river as each travels its course. If attenuation of natural flows through river routings were modeled, the routing effects of that stretch of river would be twice performed (once by nature, the other via the model) and peak flows would be reduced in error.

In order to add the influence of headwater reservoirs properly, flows were rated in the headwater models with lag functions before and during simulations. Inflow hydrographs, computed with the split ratios, were reverse lagged by the total travel time between the designated headwater location and the interface with the lower basin model. Model simulations then introduced headwater reservoir influence and lagged the outflows without attenuation by identical travel times.

### Starting Storage – Headwater Reservoirs

Starting storages of the headwater reservoirs were based on the average reservoir storages prior to the December-January 1997, March 1995, and February 1986 flood events. These events were chosen for the analysis because they provided variations in spatially distributed rainfall that best represented extreme storm runoff impacts to these basins. Thus, it was determined that these events exhibited conservative conditions of the starting storages of each of the headwater reservoirs. Storage values that appeared anomalous were discarded or discussed with the operating agency. If the average storage was greater than gross pool, then gross pool was used as the starting storage. Starting storages chosen for each headwater reservoir is presented in Table III-2.

### Headwater Simulation Product

HEC-5 computes the regulated and unregulated flows at all node locations within the model. A comparison of these two time series at the original full-basin hydrograph locations provides an excellent visual of the combined influence of all headwater reservoirs within individual watersheds. These relationships are discussed on a tributary specific basis in the results section of this report.

The products that continue on in the modeling process are the regulated hydrographs computed at the interface with the lower basin model. These time series are output by the headwater model and become the inflow data for the lower basin simulation model.

## TOP OF CONSERVATION STORAGE – FLOOD CONTROL RESERVOIRS

The required top of conservation is specified on the water control diagram for each flood damage reduction project. Typically, the top of conservation varies seasonally, as a function of a basin wetness parameter, and in some cases as a function of the concurrent storage of reservoirs upstream of the project.

The basin wetness parameter is a function of the total precipitation that has fallen to date over the watershed above the flood damage reduction project in the rainy season. To use an analogy, if one thinks of the watershed as a sponge, the basin wetness parameter would measure how much water the sponge has already absorbed. In this way, the parameter measures the antecedent moisture conditions of the watershed existing above the reservoir. The wetter the sponge, the higher the runoff and subsequent inflows to the project if a rainfall event were to occur. This parameter is often used as a variable in computing the top of conservation according to the logic that if the sponge is dry (low basin wetness), the top of conservation can be increased to provide water supply benefits without lowering the level of protection for downstream areas. However, most major rainfall events occur in wet years, which tend to have high basin wetness.

Since reservoir models were prepared to simulate specific exceedence events, computation of the top of conservation assumed that the basin wetness parameter would be high enough to reduce the top of conservation to the minimum level in all seven synthetic exceedence frequency floods; the model assumed that the sponge was wet enough to lower the top of conservation storage to its minimum level (i.e., maximum available flood space). Any seasonal variations along this minimum were included in the model input.

Top of conservation for projects with established credit space scenarios were computed as an interim process between simulations of the headwater and lower basin models.

## LOWER BASINS

Twenty-four of the 27 lower basin reservoirs have storage dedicated to flood damage reduction. Eighteen of these reservoirs, all with flood storage, are located in the San Joaquin and Tulare Basins. Major flood management reservoirs are presented in Table III-3. The largest of all Central Valley flood damage reduction projects are Shasta and Oroville Lakes, both in the Sacramento Basin. Again, model development focused on flood simulations where flood damage reduction reservoirs are encroached. The rest of this section discusses key modeling aspects for the flood damage reduction reservoirs.

### Operational Criteria

In accordance with the Flood Control Act of 1944, the USACE has established flood damage reduction criteria for all reservoirs with allocated flood space. These procedures are described in Water Control Manuals. Criteria were interpreted from published procedures and input into the model.

Key criteria included objective flow rates and locations, reservoir outflow constraints (including rate of release changes), top of conservation storage (discussed above), and Emergency Spillway Release Diagram (ESRD) operations.

### ESRD Simulation

Emergency Spillway Release Diagrams (ESRD) are formulated for reservoirs with gated spillways. Gated spillways offer the ability to store water above the spillway crest and release high flows before storage rises to the maximum allowable level. Release diagrams are developed based on the principle that if inflow is going to force releases that exceed downstream limits, emergency releases (above downstream limits) may be made before the available flood space is exhausted, designed freeboard limits are encroached, and the dam is overtopped. By increasing releases earlier in the flood event, the peak outflow required to pass the severe inflows is lowered and downstream damages are usually reduced.

# TABLE III-3

## LOWER BASIN RESEVOIRS (MAJOR FLOOD MANAGEMENT RESERVOIRS)

| Reservoir | Owner | Objective Flow (cfs) | Objective Flow Location | Gross Pool Storage (ac-ft) | Max Flood Space (ac-ft) | Credit Space Agreement |
|---|---|---|---|---|---|---|
| ***Sacramento River Basin*** | | | | | | |
| Black Butte | USACE | 15,000<br>130,000 | Below dam<br>Ord Ferry | 143,700 | 136,000 | Up to 40,000 acre-feet of storage can be transferred based on storage in East Park and Stony Gorge |
| Folsom | USBR | 115,000 | Below dam | 977,000 | 600,000[1] | Up to 200,000 acre-feet of storage can be transferred based on storage in French Meadows, Hell Hole, and Union Valley |
| Indian Valley | Yolo Cnty FCWC Dist | 20,000<br>10,000 | Below dam<br>At Rumsey | 300,600 | 40,000 | |
| New Bullards Bar | Yuba Cnty WA | 50,000<br>180,000 | Below dam<br>Marysville At Yuba Riv | 960,000 | 170,000 | |
| Oroville | DWR | 150,000<br>150,000<br>180,000<br>300,000<br>320,000 | Below dam<br>Gridley<br>Yuba City<br>Marysville<br>Nicolaus | 3,538,000 | 750,000 | |
| Shasta | USBR | 79,000<br>100,000 | Below dam<br>Bend Bridge | 4,552,000 | 1,300,000 | |
| ***San Joaquin River Basin*** | | | | | | |
| Big Dry Creek | FMFCD | 700 | Wasteway | 30,200 | 30,200 | |
| Buchanan | USACE | 7,400<br>7,000 | Below dam<br>Chowchilla River at Madera Canal | 150,000 | 45,000 | |
| Camanche | EBMUD | 5,000 | Below dam | 430,900 | 200,000 | Up to 70,000 acre-feet of storage can be transferred based on storage in Salt Springs and Lower Bear |
| Don Pedro | Turlock ID | 9,000 | Modesto | 2,030,000 | 340,000 | |
| Farmington | USACE | 2,000 | At the town of Farmington | 52,000 | 52,000 | |
| Friant | USBR | 8,000<br>6,500 | Little Dry Creek<br>Mendota Gage | 520,500 | 170,000 | Up to 85,000 acre-feet of storage can be transferred based on storage in Mammoth Pool |
| Hidden | USACE | 5,000 | Fresno River at Madera Canal | 90,000 | 65,000 | |
| Los Banos | USBR | 1,000 | Los Banos | 34,600 | 14,000 | |
| New Exchequer | Merced ID | 6,000 | Cressey | 1,024,600 | 350,000 | |
| New Hogan | USACE | 12,500 | Mormon Slough | 317,100 | 165,000 | |
| New Melones | USBR | 8,000 | Orange Blossom | 2,400,000 | 450,000 | |
| ***Tulare Lake Basin*** | | | | | | |
| Isabella | USACE | 4,600 | Kern River at Pioneer Turnout | 568,000 | 398,000 | |
| Pine Flat | USACE | 4,750<br>3,200 | Kings River North<br>Kings River South | 1,000,000 | 475,000 | Up to 162,000 acre-feet of storage can be transferred based on storage in Courtright and Wishon |
| Success | USACE | 3,200 | Tule River | 82,300 | 75,000 | |
| Terminus | USACE | 5,500 | Kaweah River at McKays Point | 143,000 | 142,000 | |

1. Assumed from the authorized Folsom Dam modifications, designed as part of the American River Project

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

Each reservoir's ESRD is unique. Some ESRD's base emergency releases on the rate the pool is rising, others as a function of the inflow. Diagrams often have ranges of pool elevations that specify the use of different sets of release criteria.

As a tool designed to have widespread application in planning studies, HEC-5 models ESRD operations generically based on pool elevation and rate of rise in the pool (HEC–5 Users Manual Version 8.0, 1998). The model can be calibrated to better reflect site-specific criteria, but will always tend towards a standard operation.

A key parameter in gated model simulations is the Recession Constant. This parameter is defined as the hours it takes for an extreme flood hydrograph to recede to approximately 40 percent of its peak flow. The Recession Constant allows HEC-5 to anticipate the total volume contained in the flood wave. Releases are then guided to pass that volume.

In this study, gated releases were modeled by entering certain input parameters directly (spillway width and pool elevations for spillway crest and surcharge levels) and adjusting the recession variable until modeled results reflected ESRD operations as closely as possible.

### Ramping up to Channel Capacity

As a default, HEC-5 tries to evacuate occupied flood space as quickly as possible (i.e., full channel capacity release when encroached 1 acre-foot). During actual operations, there is usually no immediate danger when reservoirs are at these levels and flood releases are held well below channel capacity.

Several flood damage reduction facilities had schedules relating release rate to encroachment and inflow specified in the Water Control Manual. These were incorporated directly. For most projects, variables needed to be derived to guide release decisions near the bottom of the flood space. The percent of flood space encroached was used as a variable to ramp up releases to channel capacity. All projects without specified criteria reached capacity releases at or below 50 percent encroachment.

### Physical Characteristics

All required data (elevation-capacity tables, outlet and spillway ratings, and facility schematics) are available in the Water Control Manuals.

### River Routings

Muskingum routings, procedures that delay and attenuate flows as hydrographs travel downstream, were used for all river reaches in the lower basin models. Travel times and attenuation factors (Muskingum X), as shown in Table III-4 for the Sacramento River Basin and Table III-5 for the San Joaquin River Basin, were obtained from past studies, through communication with local water agencies, or through comparisons of historic flood data. If no information was available from these sources, parameters were estimated based on length of reach, average slope, and channel characteristics.

# TABLE III-4

# HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SACRAMENTO RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 311 Shasta Dam | 302 Keswick Dam | Muskingum | 2 | 0.4 | 1.05 | 2.1 |
| 302 Keswick Dam | 289 Confluence of Clear Creek and Sacramento River | Muskingum | 3 | 0.4 | 1 | 3 |
| 299 Whiskeytown Reservoir | 292 Clear Creek at Igo | Straddle/Stagger | 1 | – | 1 | 1 |
| 299 Whiskeytown Reservoir | 302 Keswick Dam | Straddle/Stagger | – | – | 1 | 1 |
| 292 Clear Creek at Igo | 289 Confluence of Clear Creek and Sacramento River | No Routing | – | – | – | – |
| 289 Confluence of Clear Creek and Sacramento River | 280 Confluence of Sacramento River and Cow Creek | Muskingum | 2 | 0.1 | 1.1 | 2.2 |
| 286 Dummy Reservoir to receive Cow Creek | 280 Confluence of Sacramento River and Cow Creek | Muskingum | 1 | 0.2 | 1 | 1 |
| 280 Confluence of Sacramento River and Cow Creek | 276 Confluence of Sacramento River and Cottonwood Creek | Muskingum | 2 | 0.1 | 1 | 2 |
| 278 Dummy Reservoir to receive Cottonwood Creek | 276 Confluence of Sacramento River and Cottonwood Creek | Muskingum | 1 | 0.2 | 1 | 1 |
| 276 Confluence of Sacramento River and Cottonwood Creek | 272 Confluence of Sacramento River and Battle Creek | No Routing | – | – | – | – |
| 274 Dummy Reservoir to receive Battle Creek | 272 Confluence of Sacramento River and Battle Creek | Muskingum | 1 | 0.2 | 1 | 1 |
| 272 Confluence of Sacramento River and Battle Creek | 258 Sacramento River at Bend Bridge | Muskingum | 3 | 0.1 | 1 | 3 |
| 258 Sacramento River at Bend Bridge | 234 Confluence of Sacramento River and Elder Creek | Muskingum | 6 | 0.2 | 1.15 | 6.9 |
| 240 Dummy Reservoir to receive Elder Creek | 234 Confluence of Sacramento River and Elder Creek | Muskingum | 9 | 0.2 | 1 | 9 |
| 234 Confluence of Sacramento River and Elder Creek | 230 Confluence of Sacramento River and Mill Creek | No Routing | – | – | – | – |
| 232 Dummy Reservoir to receive Mill Creek | 230 Confluence of Sacramento River and Mill Creek | Muskingum | 3 | 0.2 | 1 | 3 |
| 230 Confluence of Sacramento River and Mill Creek | 225 Confluence of Sacramento River and Thomas Creek | Muskingum | 1 | 0.2 | 1.3 | 1.3 |
| 228 Dummy Reservoir to receive Thomas Creek | 225 Confluence of Sacramento River and Thomas Creek | Muskingum | 11 | 0.2 | 1 | 11 |
| 225 Confluence of Sacramento River and Thomas Creek | 220 Confluence of Sacramento River and Deer Creek | Muskingum | 1 | 0.2 | 1.4 | 1.4 |
| 223 Dummy Reservoir to receive Deer Creek | 220 Confluence of Sacramento River and Deer Creek | Muskingum | 5 | 0.2 | 1 | 5 |
| 220 Confluence of Sacramento River and Deer Creek | 218 UNET Handoff point on Sacramento River at Vina-Woodson Bridge | No Routing | – | – | – | – |

## TABLE III-4 (CONT.)

## HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SACRAMENTO RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 218 UNET handoff point on Sacramento River at Vina-Woodson Bridge | 193 Confluence of Sacramento River and Big Chico Creek | Muskingum | 6 | 0.3 | 1 | 6 |
| 210 Dummy Reservoir to receive Big Chico Creek | 205 UNET handoff point on Big Chico Creek | N o Routing | – | – | – | – |
| 205 UNET handoff point on Big Chico Creek | 193 Confluence of Sacramento River and Big Chico Creek | Muskingum | 6 | 0.2 | 1 | 6 |
| 193 Confluence of Sacramento River and Big Chico Creek | 190 Confluence of Sacramento River and Stony Creek | Muskingum | 1 | 0.2 | 0.7 | 0.7 |
| 499 Black Butte Reservoir | 420 Black Butte outflow | No Routing | – | – | – | – |
| 420 Black Butte outflow | 400 UNET handoff point on Stony Creek | Muskingum | 5 | 0.2 | 2 | 10 |
| 400 UNET handoff point on Stony Creek | 190 Confluence of Sacramento River and Stony Creek | No Routing | – | – | – | – |
| 190 Confluence of Sacramento River and Stony Creek | 184 Sacramento River at Ord Ferry | No Routing | – | – | – | – |
| 190 Confluence of Sacramento River and Stony Creek | Out of System | Diversion Routing on DR, QS, and QD cards | – | – | – | – |
| 184 Sacramento River at Ord Ferry | 169 Sacramento River at Butte City | No Routing | – | – | – | – |
| 184 Sacramento River at Ord Ferry | 1184 Dummy Reservoir to route Sacramento River at Ord Ferry overflow to Butte Basin subdivision | Diversion Routing on DR, QS, and QD cards | – | – | – | – |
| 1184 Dummy Reservoir to route Sacramento River at Ord Ferry overflow to Butte Basin subdivision | 2184 Ord-end | Muskingum | 10 | 0.1 | 4 | 40 |
| 169 Sacramento River at Butte City | 158 Moulton Weir | Muskingum | 4 | 0.2 | 2 | 8 |
| 158 Moulton Weir | 146 Colusa Weir | No Routing | – | – | – | – |
| 158 Moulton Weir | 1158 Dummy Reservoir to receive Moulton Weir diversion | Diversion Routing on DR, QS, and QD cards | – | – | – | – |
| 1158 Dummy Reservoir to receive Moulton Weir diversion | 2158 Weir-end | Muskingum | 5 | 0.1 | 4 | 20 |
| 146 Colusa Weir | 143 UNET handoff point on Colusa Weir | No Routing | – | – | – | – |
| 146 Colusa Weir | 1146 Dummy Reservoir to receive diversions to Colusa Weir | No Routing | – | – | – | – |
| 1146 Dummy Reservoir to receive diversions to Colusa Weir | 2146 Weir-end | Muskingum | 4 | 0.1 | 4 | 16 |
| 143 UNET handoff point on Colusa Weir | 119 Tisdale Weir | Muskingum | 4 | 0.25 | 2 | 8 |
| 119 Tisdale Weir | 83 Confluence of Sacramento River and Feather River | No Routing | – | – | – | – |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE III-4 (CONT.)

## HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SACRAMENTO RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 119 Tisdale Weir | 1119 Dummy Reservoir to receive diversions to Tisdale Weir | Diversion Routing on DR, QS, and QD cards | – | – | – | – |
| 1119 Dummy Reservoir to receive diversions to Tisdale Weir | 2119 End of Tisdale Weir | Muskingum | 6 | 0.2 | 2 | 12 |
| 2119 End of Tisdale Weir | 1500 Sutter Bypass | No Routing | – | – | – | – |
| 2184 Ord-end | 2222 Dummy Reservoir to receive flows from Moulton and Colusa Weirs and Ord Ferry overflow | No Routing | – | – | – | – |
| 2158 Weir-end | 2222 Dummy Reservoir to receive flows from Moulton and Colusa Weirs and Ord Ferry overflow | No Routing | – | – | – | – |
| 2146 Weir-end | 2222 Dummy Reservoir to receive flows from Moulton and Colusa Weirs and Ord Ferry overflow | No Routing | – | – | – | – |
| 2222 Dummy Reservoir to receive flows from Moulton and Colusa Weirs and Ord Ferry overflow | 2000 Butte Slough near Meridian | No Routing | – | – | – | – |
| 2111 Dummy Reservoir to receive Butte Creek near Chico | 2100 UNET handoff point on Butte Creek | No Routing | – | – | – | – |
| 2100 UNET handoff point on Butte Creek | 2000 Butte Slough near Meridian | Muskingum | 21 | 0.2 | 1 | 21 |
| 2000 Butte Slough near Meridian | 1500 Sutter Bypass | Muskingum | 8 | 0.2 | 2 | 16 |
| 1500 Sutter Bypass | 83 Confluence of Sacramento River and Feather River | Muskingum | 2 | 0.2 | 2 | 4 |
| 599 Oroville Dam | 560 UNET handoff point for Feather River at Thermalito | No Routing | – | – | – | – |
| 560 UNET handoff point for Feather River at Thermalito | 551 Feather River at Gridley | No Routing | – | – | – | – |
| 551 Feather River at Gridley | 550 UNET handoff point for Feather River at Gridley | Muskingum | 3 | 0.2 | 1 | 3 |
| 550 UNET handoff point for Feather River at Gridley | 540 Confluence of Feather River and Honcut Creek | Muskingum | 1 | 0.17 | 1 | 1 |
| 545 Dummy Reservoir to receive Feather River local | 543 UNET handoff point for Feather River local | No Routing | – | – | – | – |
| 543 UNET handoff point for Feather River local | 540 Confluence of Feather River and Honcut Creek | No Routing | – | – | – | – |
| 540 Confluence of Feather River and Honcut Creek | 528 Feather River at Yuba City | Muskingum | 2 | 0.17 | 2 | 4 |
| 528 Feather River at Yuba City | 527 Confluence of Feather River and Yuba River | No Routing | – | – | – | – |
| 699 Bullards Bar Reservoir (North Fork Yuba River) | 690 Confluence of North Fork Yuba River and Middle Fork Yuba River | Muskingum | 1 | 0.15 | 1 | 1 |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE III-4 (CONT.)

# HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SACRAMENTO RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 690 Confluence of North Fork Yuba River and Middle Fork Yuba River | 680 Confluence of Middle Fork Yuba River and South Fork Yuba River | Muskingum | 3 | 0.15 | 1 | 3 |
| 680 Confluence of Middle Fork Yuba River and South Fork Yuba River | 675 Englebright Dam | No Routing | – | – | – | – |
| 675 Englebright Dam | 673 UNET handoff point at Englebright Dam | Muskingum | 1 | 0.15 | 1 | 1 |
| 673 UNET handoff point at Englebright Dam | 665 Confluence of Yuba River and Deer Creek | No Routing | – | – | – | – |
| 670 Dummy Reservoir to receive Deer Creek | 668 UNET handoff point for Deer Creek | No Routing | – | – | – | – |
| 668 UNET handoff point for Deer Creek | 665 Confluence of Yuba River and Deer Creek | No Routing | – | – | – | – |
| 665 Confluence of Yuba River and Deer Creek | 660 Yuba River below Deer Creek | No Routing | – | – | – | – |
| 660 Yuba River below Deer Creek | 650 Confluence of Yuba River and Dry Creek | Muskingum | 2 | 0.15 | 1 | 2 |
| 655 Dummy Reservoir to receive Dry Creek | 652 UNET handoff point for Dry Creek near Yuba | No Routing | – | – | – | – |
| 652 UNET handoff point for Dry Creek near Yuba | 650 Confluence of Yuba River and Dry Creek | No Routing | – | – | – | – |
| 650 Confluence of Yuba River and Dry Creek | 601 Gage at Yuba River near Marysville | Muskingum | 2 | 0.15 | 0.75 | 1.5 |
| 601 Gage at Yuba River near Marysville | 527 Confluence of Feather River and Yuba River | Muskingum | 1 | 0.15 | 1 | 1 |
| 527 Confluence of Feather River and Yuba River | 512 Confluence of Bear Creek and Feather River | Muskingum | 8 | 0.35 | 1 | 8 |
| 520 Dummy Reservoir to receive Bear Creek | 518 UNET handoff point for Bear Creek | No Routing | – | – | – | – |
| 518 UNET handoff point for Bear Creek | 514 Confluence of Bear Creek and Dry Creek | Muskingum | 2 | 0.2 | 1 | 2 |
| 516 Dummy Reservoir to receive Dry Creek near Wheatland | 515 UNET handoff point for Dry Bear | No Routing | – | – | – | – |
| 515 UNET handoff point for Dry Bear | 514 Confluence of Dry and Bear Creeks | Muskingum | 2 | 0.2 | 1 | 2 |
| 514 Confluence of Dry and Bear Creeks | 512 Confluence of Bear Creek and Feather River | Muskingum | 2 | 0.2 | 1 | 2 |
| 512 Confluence of Bear Creek and Feather River | 510 Feather River near Nicolaus | Muskingum | 2 | 0.35 | 1 | 2 |
| 510 Feather River near Nicolaus | 83 Confluence of Sacramento River and Feather River | Muskingum | 2 | 0.2 | 2 | 4 |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE III-4 (CONT.)

## HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SACRAMENTO RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 83 Confluence of Sacramento River and Feather River | 82 Fremont Weir | No Routing | – | – | – | – |
| 82 Fremont Weir | 64 Confluence of Sacramento River and American River | Muskingum | 4 | 0.2 | 2 | 8 |
| 82 Fremont Weir | 1082 Weir-rout | No Routing | – | – | – | – |
| 1082 Weir-rout | 3333 Dummy Reservoir for start of Yolo Bypass | Muskingum | 3 | 0.2 | 2 | 6 |
| 799 Folsom Dam | 780 American River at Fair Oaks | Muskingum | 2 | 0.4 | 1 | 2 |
| 780 American River at Fair Oaks | 775 UNET handoff point for American River at Fair Oaks | No Routing | – | – | – | – |
| 775 UNET handoff point for American River at Fair Oaks | 770 American River at H Street Gage | Muskingum | 2 | 0.2 | 2 | 4 |
| 770 American River at H Street Gage | 64 Confluence of Sacramento River and American River | Muskingum | 1 | 0.2 | 2 | 2 |
| 64 Confluence of Sacramento River and American River | 63 Sacramento Weir on Sacramento River | No Routing | – | – | – | – |
| 63 Sacramento Weir on Sacramento River | 60 Sacramento River at I Street Gage | Muskingum | 2 | 0.2 | 2.5 | 5 |
| 63 Sacramento Weir on Sacramento River | 3080 Yolo Bypass at I-80 Causeway | No Routing | – | – | – | – |
| 60 Sacramento River at I Street Gage | 48 Sacramento River at Freeport | Muskingum | 4 | 0.2 | 2 | 8 |
| 48 Sacramento River at Freeport | 12 Confluence of Sacramento River and Yolo Bypass at Rio Vista Gage | Muskingum | 4 | 0.2 | 2 | 8 |
| 3333 Dummy Reservoir for start of Yolo Bypass | 3300 Confluence of Colusa Drain and Fremont Weir | No Routing | – | – | – | – |
| 3300 Confluence of Colusa Drain and Fremont Weir | 3200 Yolo Bypass near Woodland | Muskingum | 1 | 0.2 | 2 | 2 |
| 398 Clear Lake Reservoir | 397 Cache Creek near Lower Lake | No Routing | – | – | – | – |
| 397 Cache Creek near Lower Lake | 396 Cache Creek at Rumsey | Muskingum | 8 | 0.28 | 1 | 8 |
| 399 Indian Valley Reservoir | 396 Cache Creek at Rumsey | Muskingum | 7 | 0.2 | 1 | 7 |
| 396 Cache Creek at Rumsey | 3955 Cache Creek at Capay | Muskingum | 3 | 0.3 | 1 | 3 |
| 3955 Cache Creek at Capay | 395 Cache Creek at Yolo | Muskingum | 7 | 0.2 | 1 | 7 |
| 395 Cache Creek at Yolo | 394 UNET handoff point at Cache Creek Settling Basin | No Routing | – | – | – | – |
| 394 UNET handoff point at Cache Creek Settling Basin | 3200 Yolo Bypass near Woodland | No Routing | – | – | – | – |
| 3200 Yolo Bypass near Woodland | 3080 Yolo Bypass at I-80 Causeway | Muskingum | 1 | 0.2 | 1 | 1 |
| 3080 Yolo Bypass at I-80 Causeway | 3020 Confluence of Yolo Bypass and Putah Creek | Muskingum | 3 | 0.2 | 2 | 6 |
| 099 Lake Berryessa and Monticello Dam | 80 Putah Diversion Dam | Muskingum | 1 | 0 | 3 | 3 |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE III-4 (CONT.)

## HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SACRAMENTO RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 80 Putah Diversion Dam | 075 Putah Creek near Winters | Muskingum | 1 | 0 | 24 | 24 |
| 80 Putah Diversion Dam | Out of System | Diversion Routing on DR, QS, and QD cards | – | – | – | – |
| 075 Putah Creek near Winters | 65 UNET handoff point for Putah Creek southeast of Davis | No Routing | – | – | – | – |
| 65 UNET handoff point for Putah Creek southeast of Davis | 3020 Confluence of Yolo Bypass and Putah Creek | No Routing | – | – | – | – |
| 3020 Confluence of Yolo Bypass and Putah Creek | 3012 Yolo Bypass at Lisbon | No Routing | – | – | – | – |
| 3012 Yolo Bypass at Lisbon | 12 Confluence of Sacramento River and Yolo Bypass at Rio Vista Gage | Muskingum | 8 | 0.2 | 2 | 16 |
| 12 Confluence of Sacramento River and Yolo Bypass at Rio Vista Gage | 999 End of Project | No Routing | – | – | – | – |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE III-5

# HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SAN JOAQUIN RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 369 Pine Flat Reservoir | 360 Intersection of Kings River and Friant Kern Canal | Muskingum | 1 | 0.2 | 2 | 2 |
| 360 Intersection of Kings River and Friant Kern Canal | 3350 Information point Inflow to Army Weir | Muskingum | 4 | 0.1 | 5 | 20 |
| 3350 Information point Inflow to Army Weir | 350 Army Weir | No Routing | – | – | – | 0 |
| 350 Army Weir | 3340 Information point Inflow to Crecent Weir | Muskingum | 2 | 0.1 | 4 | 8 |
| 3340 Information point Inflow to Crecent Weir | 340 Crescent Weir | No Routing | – | – | – | 0 |
| 340 Crescent Weir | 330 James Bypass | Muskingum | 30 | 0.15 | 1 | 30 |
| 330 James Bypass | 333 UNET handoff point for James Bypass | Muskingum | 2 | 0.2 | 1.5 | 3 |
| 333 UNET handoff point for James Bypass | 205 Mendota Gage | Muskingum | 10 | 0.2 | 1 | 10 |
| 497 Big Dry Creek Dam and Diversion | 496 Little Dry Creek at Wasteway | Muskingum | 1 | 0.25 | 1 | 1 |
| 496 Little Dry Creek at Wasteway | 216 UNET handoff point on Little Dry Creek | Muskingum | 1 | 0.25 | 1 | 1 |
| 216 UNET handoff point on Little Dry Creek | 250 Confluence of San Joaquin River and Little Dry Creek | No Routing | – | – | – | – |
| 270 Friant Dam | 260 UNET point Confluence of Friant Releases and Cottonwood Creek | No Routing | – | – | – | – |
| 260 UNET point Confluence of Friant Releases and Cottonwood Creek | 250 Confluence of San Joaquin River and Little Dry Creek | Muskingum | 3 | 0.25 | 1 | 3 |
| 250 Confluence of San Joaquin River and Little Dry Creek | 215 San Joaquin River at Gravelly Ford | Muskingum | 32 | 0.2 | 1 | 32 |
| 215 San Joaquin River at Gravelly Ford | 445 Information Point for Inflow to Chowchilla Bypass junction | Muskingum | 14 | 0.15 | 1 | 14 |
| 445 Information Point for Inflow to Chowchilla Bypass junction | 452 Junction of Chowchilla Bypass and San Joaquin River | No Routing | – | – | – | – |
| 452 Junction of Chowchilla Bypass and San Joaquin River | 1452 Dummy Reservoir to receive Diversions from San Joaquin River to Chowchilla Bypass | No Routing | – | – | – | – |
| 452 Junction of Chowchilla Bypass and San Joaquin River | 450 San Joaquin below Diversion | No Routing | – | – | – | – |
| 450 San Joaquin below Diversion | 205 Mendota Gage | Muskingum | 14 | 0.15 | 1 | 14 |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE III-5 (CONT.)

## HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SAN JOAQUIN RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 1452 Dummy Reservoir to receive Diversions from San Joaquin River to Chowchilla Bypass | 436 Intersection of Chowchilla Bypass with Fresno River | Muskingum | 6 | 0.1 | 2 | 12 |
| 205 Mendota Gage | 433 El Nido | Muskingum | 22 | 0.17 | 2 | 44 |
| 499 Hidden Dam Hensley Lake (Fresno River) | 416 Fresno River at Madera Canal | Muskingum | 4 | 0.2 | 1 | 4 |
| 416 Fresno River at Madera Canal | 426 UNET handoff point on the Fresno River | Muskingum | 7 | 0.2 | 2 | 14 |
| 426 UNET handoff point on the Fresno River | 436 Fresno River at Chowchilla Bypass | Muskingum | 4 | 0.2 | 2 | 8 |
| 436 Fresno River at Chowchilla Bypass | 435 Intersection of Chowchilla River and Chowchilla Bypass | Muskingum | 3 | 0.25 | 2 | 6 |
| 498 Buchanan Dam (Chowchilla River) | 418 Chowchilla River at Madera Canal | Muskingum | 2 | 0.2 | 2 | 4 |
| 418 Chowchilla River at Madera Canal | 1418 Bifurcation to Ash and Brenda Sloughs | No Routing | – | – | – | – |
| 1418 Bifurcation to Ash and Brenda Sloughs | 1419 Dummy Reservoir to receive diversions to Ash Slough | No Routing | – | – | – | – |
| 1418 Bifurcation to Ash and Brenda Sloughs | 428 UNET handoff point on Brenda Slough | Muskingum | 5 | 0.2 | 2 | 10 |
| 1419 Dummy Reservoir to receive diversions to Ash Slough | 1428 UNET handoff point on Ash Slough | Muskingum | 7 | 0.2 | 2 | 14 |
| 428 UNET handoff point on Brenda Slough | 435 Chowchilla River at Chowchilla Bypass | Muskingum | 3 | 0.2 | 2 | 6 |
| 1428 UNET handoff point on Ash Slough | 435 Chowchilla River at Chowchilla Bypass | Muskingum | 3 | 0.2 | 2 | 6 |
| 435 Chowchilla River at Chowchilla Bypass | 433 El Nido | Muskingum | 4 | 0.2 | 2 | 8 |
| 433 El Nido | 422 Eastside Bypass/Mariposa Bypass Confluence | Muskingum | 10 | 0.2 | 2 | 20 |
| 422 Eastside Bypass/Mariposa Bypass Confluence | 1422 Diversion from Eastside Bypass to Mariposa Bypass | No Routing | – | – | – | – |
| 422 Eastside Bypass/Mariposa Bypass Confluence | 402 Eastside Bypass minus Mariposa Bypass plus Mariposa Bypass plus Owens | Muskingum | 1 | 0.3 | 1 | 1 |
| 1422 Diversion from Eastside Bypass to Mariposa Bypass | 147 Confluence of Mariposa Bypass with San Joaquin River | Muskingum | 2 | 0.2 | 1 | 2 |
| 147 Confluence of Mariposa Bypass with San Joaquin River | 136 San Joaquin River near Stevinson | Muskingum | 3 | 0.2 | 2 | 6 |
| 66 Owens Reservoir | 166 Owens Diversion | Muskingum | 4 | 0.3 | 1 | 4 |
| 88 Mariposa Reservoir | 188 Confluence of Mariposa Releases with Owens Diversion flow | Muskingum | 6 | 0.3 | 1 | 6 |
| 44 Dummy Reservoir to receive Miles Creek | 144 Confluence with Miles Creek | Muskingum | 10 | 0.2 | 1 | 10 |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE III-5 (CONT.)

## HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SAN JOAQUIN RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 22 Burns Reservoir | 123 Confluence of Burns with Black Rascal Diversion Inflow | Muskingum | 8 | 0.3 | 1 | 8 |
| 33 Bear Reservoir | 123 Confluence of Burns with Black Rascal Diversion Inflow | Muskingum | 8 | 0.3 | 1 | 8 |
| 166 Owens Diversion | 188 Confluence with Owens Diversion | Muskingum | 1 | 0.2 | 1 | 1 |
| 188 Confluence of Owens Diversion | 195 Confluence with Deadman | Muskingum | 12 | 0.2 | 1 | 12 |
| 195 Confluence with Deadman | 198 UNET handoff point on Mariposa Creek | Muskingum | 14 | 0.2 | 1 | 14 |
| 198 UNET handoff point on Mariposa Creek | 402 Eastside Bypass minus Mariposa Bypass plus Mariposa Bypass plus Owens | No Routing | – | – | – | 0 |
| 144 Confluence of Miles Creek | 154 UNET handoff point on Owens Creek | Muskingum | 10 | 0.2 | 1 | 10 |
| 154 UNET handoff point on Owens Creek | 402 Confluence of Eastside Bypass with Mariposa and Owens | No Routing | – | – | – | 0 |
| 402 Confluence of Eastside Bypass with Mariposa and Owens | 401 Confluence of Eastside Bypass with Bear and Burns | Muskingum | 3 | 0.2 | 1 | 3 |
| 123 Confluence of Burns with Black Rascal Diversion Inflow | 133 Bear Creek at Mckee Road | Muskingum | 3 | 0.3 | 1 | 3 |
| 133 Bear Creek at Mckee Road | 143 UNET handoff point on Bear Creek | Muskingum | 9 | 0.2 | 2 | 18 |
| 143 UNET handoff point on Bear Creek | 401 Confluence of Eastside Bypass with Bear and Burns | Muskingum | 3 | 0.2 | 2 | 6 |
| 401 Confluence of Eastside Bypass with Bear and Burns | 136 San Joaquin River near Stevinson | Muskingum | 2 | 0.2 | 1 | 2 |
| 136 San Joaquin River near Stevinson | 121 San Joaquin River near Newman | Muskingum | 16 | 0.2 | 2 | 32 |
| 599 Los Banos Reservoir | 590 Los Banos Creek at SFG | Muskingum | 4 | 0.2 | 2.5 | 10 |
| 590 Los Banos Creek at SFG | 585 Los Banos Creek below SFG | No Routing | | | | 0 |
| 585 Los Banos Creek below SFG | 580 UNET handoff point on Los Banos Creek | Muskingum | 5 | 0.2 | 2.5 | 12.5 |
| 580 UNET handoff point on Los Banos Creek | 121 San Joaquin River near Newman | No Routing | – | – | – | 0 |
| 699 New Exchequer Dam/Lake McClure | 690 Merced River at Cressey | Muskingum | 10 | 0.2 | 2 | 20 |
| 690 Merced River at Cressey | 685 UNET handoff point on Merced River below Cressey | Muskingum | 2 | 0.2 | 1.75 | 3.5 |
| 685 UNET handoff point on Merced River below Cressey | 680 UNET handoff point on Merced River near Stevinson | Muskingum | 4 | 0.2 | 2 | 8 |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE III-5 (CONT.)

# HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SAN JOAQUIN RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 680 UNET handoff point on Merced River near Stevinson | 121 San Joaquin River near Newman | Muskingum | 11 | 0.2 | 1 | 11 |
| 121 San Joaquin River near Newman | 1211 Confluence with Orestimba Creek | Muskingum | 5 | 0.15 | 1 | 5 |
| 1214 Dummy Reservoir to receive Orestimba Creek | 1213 UNET handoff point on Orestimba Creek | Muskingum | 10 | 0.1 | 1 | 10 |
| 1213 UNET handoff point on Orestimba Creek | 1211 Confluence with Orestimba Creek | No Routing | – | – | – | 0 |
| 1211 Confluence with Orestimba Creek | 1212 Confluence with Del Puerto Creek | Muskingum | 5 | 0.15 | 1 | 5 |
| 1222 Dummy Reservoir to receive Del Puerto Creek | 1221 UNET handoff point on Del Puerto Creek | Muskingum | 5 | 0.2 | 1.1 | 5.5 |
| 1221 UNET handoff point on Del Puerto Creek | 1212 Confluence with Del Puerto Creek | No Routing | – | – | – | 0 |
| 1212 Confluence with Del Puerto Creek | 120 San Joaquin River at Maze Road Bridge | Muskingum | 5 | 0.15 | 2 | 10 |
| 799 Don Pedro Dam on Tuolumne River | 795 UNET handoff point on Tuolumne River at Santa Fe Avenue | Muskingum | 9 | 0.1 | 2 | 18 |
| 792 Dummy Reservoir to receive Dry Creek near Modesto | 791 UNET handoff point on Dry Creek near Modesto | No Routing | – | – | – | 0 |
| 791 UNET handoff point on Dry Creek near Modesto | 790 Tuolumne River at Modesto | Muskingum | 2 | 0.2 | 1 | 2 |
| 795 UNET handoff point on Tuolumne River at Santa Fe Avenue | 790 Tuolumne River at Modesto | Muskingum | 2 | 0.15 | 1 | 2 |
| 790 Tuolumne River at Modesto | 780 UNET handoff point on Tuolumne River at Modesto | No Routing | – | – | – | 0 |
| 780 UNET handoff point on Tuolumne River at Modesto | 120 San Joaquin River at Maze Road Bridge | Muskingum | 4 | 0.15 | 2 | 8 |
| 120 San Joaquin River at Maze Road Bridge | 119 San Joaquin River near Vernalis | Muskingum | 4 | 0.15 | 2 | 8 |
| 899 New Melones Reservoir on Stanislaus River | 8998 Intermediate point between Melones and Tulloch (local flow input point) | No Routing | – | – | – | 0 |
| 8998 Intermediate point between Melones and Tulloch (local flow input point) | 898 Tulloch Reservoir on Stanislaus River downstream from Melones | No Routing | – | – | – | 0 |
| 898 Tulloch Reservoir on Stanislaus River downstream from Melones | 890 Stanislaus River at Orange Blossom Bridge | Muskingum | 2 | 0.2 | 2 | 4 |
| 890 Stanislaus River at Orange Blossom Bridge | 889 UNET handoff point on Stanislaus River at Orange Blossom Bridge | No Routing | – | – | – | 0 |
| 889 UNET handoff point on Stanislaus River at Orange Blossom Bridge | 880 Stanislaus River at Ripon | Muskingum | 5 | 0.1 | 3 | 15 |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE III-5 (CONT.)

## HEC-5 LOWER BASIN ROUTING PARAMETERS FOR THE SAN JOAQUIN RIVER BASIN

| From Node | To Node | Routing Type | Number of Sub-reaches | Muskingum X | Travel Time per Subreach (hrs) | Total Travel Time (hrs) |
|---|---|---|---|---|---|---|
| 880 Stanislaus River at Ripon | 879 UNET handoff point on Stanislaus River at Ripon | No Routing | – | – | – | 0 |
| 879 UNET handoff point on Stanislaus River at Ripon | 119 San Joaquin River near Vernalis | Muskingum | 8 | 0.2 | 2 | 16 |
| 119 San Joaquin River near Vernalis | 115 San Joaquin River at I-5 | Muskingum | 6 | 0.2 | 2 | 12 |
| 115 San Joaquin River at I-5 | 110 San Joaquin River at Stockton | Muskingum | 7 | 0.2 | 2 | 14 |
| 99 Dummy Reservoir to bring in Duck Creek flow | 996 Intermediate point | No Routing | – | – | – | 0 |
| 996 Intermediate point | 65 Duck Creek Diversion | No Routing | – | – | – | 0 |
| 65 Duck Creek Diversion | 23 UNET handoff point FCS | Muskingum | 6 | 0.2 | 1 | 6 |
| 65 Duck Creek Diversion | 665 Duck Creek Diversion to Littlejohn Creek at Farmington | No Routing | – | – | – | 0 |
| 665 Duck Creek Diversion to Littlejohn Creek at Farmington | 25 Littlejohn Creek at Farmington Reservoir | Muskingum | 1 | 0.2 | 1 | 1 |
| 10 Farmington Reservoir | 25 Littlejohn Creek at Farmington Reservoir | Muskingum | 1 | 0.3 | 1.6 | 1. 67 |
| 25 Littlejohn Creek at Farmington Reservoir | 24 Lone Tree | Muskingum | 6 | 0.2 | 1 | 6 |
| 24 Lone Tree | 23 UNET handoff point FCS | Muskingum | 1 | 0.2 | 1 | 1 |
| 23 UNET handoff point FCS | 110 San Joaquin River at Stockton | No Routing | – | – | – | 0 |
| 110 San Joaquin River at Stockton | 105 Terminus | Muskingum | 5 | 0.2 | 1 | 5 |
| 105 Terminus | 999 Nirvana | No Routing | – | – | – | 0 |

### Local Flows

Local flows are unregulated tributaries that join with larger tributaries between reservoirs in series or between a flood damage reduction reservoir and its objective flow location. In this study, local flows were modeled in one of two ways. Hydrographs for local flows were either produced through procedures outlined in Attachment B - Synthetic Hydrology or local flows were estimated as a percentage or ratio of a nearby natural flow hydrograph. Percentages were estimated based on comparisons of short duration maxima (peak, 1-, and 3-day) for the local and nearby natural hydrographs.

These local flows were input into the HEC-5 model and influenced reservoir outflows by filling some or all of the downstream channel capacity.

The natural flow hydrographs to which these ratios were applied are provided in the column titled ‘Source’ in Tables III-6 and III-7.

## Starting Storage

During model simulations the initial starting storages are set at the top of conservation for all flood damage reduction projects. Top of conservation values for projects with established credit space scenarios are computed as an interim process between simulations of the headwater and lower basin models. The top of conservation parameter is therefore variable with each iterative time-step simulation of the lower basin reservoirs that operate with formal credit space agreements.

## Simulation Product

The lower basin simulation is the final step in translating the seven synthetic exceedence frequency natural-flow hydrographs, produced in the Synthetic Hydrology Study (Appendix B), to seven simulated regulated outflow hydrographs. In the Comprehensive Study modeling procedure, these results provide the hydrologic input for hydraulic models, which perform detailed routing of the flows through floodplain areas. Floodplains are delineated and stage-frequency information is passed to economic modelers for use in determining damages associated with the occurrence of each of the seven synthetic exceedence frequency events.

**TABLE III-6**

**LOCAL FLOW ASSUMPTIONS FOR THE SACRAMENTO RIVER BASIN**

| Location | Ratio | Source |
|---|---|---|
| Watershed area below Shasta, Whiskeytown, and gage locations on Cow, Cottonwood, and Battle Creeks and above Bend Bridge | 0.47 | Combined flows of Cow, Cottonwood, and Battle Creek gages |
| Watershed area below Bend Bridge, Black Butte Reservoir, and gage locations on Mill, Elder, Thomes, Deer, and Big Chico Creeks and above Ord Ferry | 0.55 | Combined flows of Mill, Elder, Thomes, Deer, and Big Chico Creek gages |
| Honcut Creek at Feather River | 0.0925 | Feather River natural flow at Oroville Dam |
| Watershed area between New Bullards Bar, the Our House gage, Jones Bar gage, and the Yuba River below Englebright Dam | 0.28 | New Bullards Bar inflow |
| Dry Creek near Browns Valley (Yuba River) | 1 | Deer Creek near Smartsville |
| Dry Creek at the Bear River near Wheatland | 0.15 | Bear River natural flow near Wheatland |
| Watershed area between the Grigsby Riffles and Cache Creek near Lower Lake gage | 0.13 | Indian Valley inflow |
| Watershed area between Cache Creek near Lower Lake gage, Indian Valley Reservoir, and Cache Creek at Rumsey | 1.65 | Indian Valley inflow |
| Watershed area between Cache Creek at Rumsey and Cache Creek at Capay | 0.4 | Indian Valley inflow |
| Note: The following local flow streams were investigated in the Synthetic Hydrology. Therefore, no local flow ratios were needed for Cow Creek, Cottonwood Creek, Battle Creek, Mill Creek, Elder Creek, Thomes Creek, Deer Creek (near Vina), Big Chico Creek, and Deer Creek (near Smartsville). | | |

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE III-7

## LOCAL FLOW ASSUMPTIONS FOR THE SAN JOAQUIN RIVER BASIN

| Location | Ratio | Source |
|---|---|---|
| Mill and Hughes Creeks, Kings River Basin | 0.1 | Kings River natural flow at Pine Flat Dam |
| Little Dry Creek at confluence with San Joaquin River | 0.95 | Big Dry Creek reservoir inflow |
| Cottonwood Creek at confluence with San Joaquin River | 0.25 | Big Dry Creek reservoir inflow |
| Watershed area between Hidden Dam (Hensley Lake) and Madera Canal | 0.1 | Hensley Lake inflow |
| Watershed area between Buchanan Dam (H.V. Eastman Lake) and Madera Canal | 0.1 | Eastman Lake inflow |
| Miles Creek at confluence with Owens Creek | 0.7 | Owens inflow |
| Watershed area between Owens and Mariposa Dams and the confluence of Owens Diversion | 0.28 | Owens inflow |
| Deadman and Dutchman Creeks and watershed area between Owens Diversion and Deadman confluence | 2.2 | Owens inflow |
| Watershed area between Owens Creek at the Miles confluence and the Eastside Bypass | 0.25 | Owens inflow |
| Black Rascal Creek at Diversion | 0.53 | Burns inflow |
| Watershed area between Burns and Bear Dams and McKee Road | 0.3 | Bear inflow |
| Watershed area between McKee Road and Bear Creek near the Eastside Bypass | 0.2 | Bear inflow |
| Watershed area between Los Banos Reservoir and Los Banos Creek below the Santa Fe Grade | 0.2 | Los Banos inflow |
| Dry Creek at the Merced River | 0.07 | New Exchequer inflow |
| Watershed area between New Melones and Tulloch Reservoirs on the Stanislaus River | 0.07 | Stanislaus River natural flow at New Melones Dam |
| Watershed area between Tulloch Dam and the Stanislaus River at Orange Blossom Bridge | 0.01 | Stanislaus River natural flow at New Melones Dam |
| Watershed area between Duck Creek near Farmington Gage and the Duck Creek Diversion | 2.4 | Duck Creek near Farmington gage site |
| Watershed area between Farmington Dam and the confluence of Littlejohn Creek and the Duck Creek Diversion | 0.04 | Farmington inflow |
| Lone Tree Creek at Littlejohn Creek | 0.68 | Duck Creek near Farmington gage site |
| Deer Creek at the confluence with the Cosumnes River | 0.07 | Natural flow for the Cosumnes River at Michigan Bar |
| Dry Creek near Galt | 0.4 | Natural flow for the Cosumnes River at Michigan Bar |

Note:

Dry Creek (near Modesto) was analyzed in the Synthetic Hydrology. Therefore, no local flow ratio was needed for this stream.

# CHAPTER IV

# MODEL CALIBRATION AND VERIFICATION

## GENERAL

Models for flood damage reduction projects were calibrated individually using the 1997 and 1995 flood events. The key calibration variable was related to gate operations, specifically the Recession Constant. For additional verification, HEC-5 flood simulations were performed through the routing of historic or design events published in each reservoir's Water Control Manual. The results were then compared with manual routings based on the emergency spillway release diagram (ESRD). The Recession Constant was adjusted iteratively until results reflected ESRD operations as closely as possible.

Verification and calibration of these models was unique in that the modeling goal was not to reflect recorded history. Instead, modeling sought to portray "by the book" operations. As severe floods dictate event-specific operations, an ideal verification data set does not exist. Modelers inspected simulation results to confirm agreement with operations under existing conditions for headwater and flood damage reduction projects.

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# CHAPTER V

# BASELINE MODELING RESULTS AND DISCUSSION

## OVERVIEW

Generally, model output is in good agreement on by the book operations (see Figures C.1-1a to C.2-9). Reservoir operations for downstream local flow at the first operational point are excellent. Models did experience some difficulty simulating systems with multiple operational points where one or more points were located a long distance from the reservoir (i.e., Black Butte operating for Ord Ferry or Friant Dam operating for flows at Mendota).

For some reservoirs, the design structure and capabilities of HEC-5 limited the accuracy of model simulations. This was true in the modeling of gated spillway operations. HEC-5 was not designed to reflect all details of complicated ESRD's, but the model did perform acceptably for all facilities and often produced results in excellent agreement with manual routings.

The focus on by the book operations was needed to reflect baseline conditions, but could actually mask existing problems. For example, flood releases on Stony Creek and the Mokelumne River create erosion and conveyance problems below design levels of channel capacity. As simulations are performed with the full design capacity as a variable, HEC-5 results (by design) will not illustrate these problems. In the Comprehensive Study, reservoir simulation results provide input data for hydraulic models that execute detailed routings of river reaches downstream of the reservoirs. The hydraulic models may draw attention to the problems, but the efforts of the Comprehensive Study must consider the potential masking of problems through modeling procedures.

The remainder of this section is formatted as a series of short discussions for each major tributary in a north to south progression. Tables V-1 and V-2 provide data detailing the simulated influence of headwater reservoirs. Simulation results for all tributaries are available in Attachment C.1 - Controlling Reservoirs and Attachment C.2 – Downstream Control Points.

# TABLE V-1

## EFFECTS OF HEADWATER REGULATIONS - SACRAMENTO BASIN

| **Sacramento Basin** | | | | | |
|---|---|---|---|---|---|
| **Annual Percent Chance Exceedence** | | **Reservoir** | | | |
| | | **Shasta** | **Black Butte** | **Oroville** | **Folsom** |
| 50% | % Peak Reduced | 2.8 | 20.3 | 11.1 | 9.5 |
| | Total Volume Captured (ac-ft) | 5,086 | 616 | -43,804 | -47,274 |
| 10% | % Peak Reduced | 1.8 | 20.3 | 15.4 | 12.6 |
| | Total Volume Captured (ac-ft) | 11,038 | 616 | 113,360 | 53,230 |
| 4% | % Peak Reduced | 1.9 | 15.7 | 15.0 | 11.5 |
| | Total Volume Captured (ac-ft) | 12,325 | 900 | 183,292 | 98,391 |
| 2% | % Peak Reduced | 1.8 | 11.0 | 13.6 | 11.0 |
| | Total Volume Captured (ac-ft) | 13,156 | 1,788 | 214,465 | 133,284 |
| 1% | % Peak Reduced | 1.8 | 8.6 | 12.6 | 10.8 |
| | Total Volume Captured (ac-ft) | 13,876 | 2,370 | 264,970 | 160,276 |
| 0.5% | % Peak Reduced | -0.2 | 8.4 | 12.3 | 10.6 |
| | Total Volume Captured (ac-ft) | 14,532 | 2,913 | 314,175 | 170,907 |
| 0.2% | % Peak Reduced | 0.9 | 8.3 | 12.3 | 9.8 |
| | Total Volume Captured (ac-ft) | 14,842 | 3,528 | 369,800 | 172,366 |

Notes:

a) % Peak Reduced = ((Maximum Unregulated Inflow)-(Maximum Regulated Inflow))/(Maximum Unregulated Inflow) X 100%

b) Total Volume Captured = (Total Unregulated Inflow - Total Regulated Inflow)*30 days *(1.98 ac-ft/day/cfs)

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE V-2

# EFFECTS OF HEADWATER REGULATIONS - SAN JOAQUIN BASIN

| San Joaquin Basin | | | | | |
|---|---|---|---|---|---|
| **Annual Percent Chance Exceedence** | | **Reservoir** | | | |
| | | **Pine Flat** | **Friant** | **Don Pedro** | **New Melones** |
| 50% | % Peak Reduced | 3.9 | 45.4 | 33.4 | 25.7 |
| | Total Volume Captured (ac-ft) | -35,326 | -20,011 | 1,649 | -2,158 |
| 10% | % Peak Reduced | 8.1 | 60.8 | 37.2 | 28.5 |
| | Total Volume Captured (ac-ft) | -23,858 | 21,710 | 65,537 | 46,283 |
| 4% | % Peak Reduced | 8.9 | 51.7 | 28.5 | 26.6 |
| | Total Volume Captured (ac-ft) | -12,600 | 92,259 | 87,224 | 71,355 |
| 2% | % Peak Reduced | 9.1 | 52.8 | 27.0 | 22.9 |
| | Total Volume Captured (ac-ft) | -2,836 | 129,133 | 97,058 | 81,439 |
| 1% | % Peak Reduced | 9.3 | 49.3 | 24.5 | 22.2 |
| | Total Volume Captured (ac-ft) | 7,996 | 147,839 | 97,547 | 87,947 |
| 0.5% | % Peak Reduced | 9.5 | 40.0 | 24.5 | 21.9 |
| | Total Volume Captured (ac-ft) | 20,191 | 166,735 | 97,634 | 94,493 |
| 0.2% | % Peak Reduced | 9.6 | 39.3 | 21.2 | 20.7 |
| | Total Volume Captured (ac-ft) | 38,397 | 189,870 | 94,455 | 103,012 |

Notes:

a) % Peak Reduced = ((Maximum Unregulated Inflow)-(Maximum Regulated Inflow))/(Maximum Unregulated Inflow) X 100%

b) Total Volume Captured = (Total Unregulated Inflow - Total Regulated Inflow)*30 days *(1.98 ac-ft/day/cfs)

## SACRAMENTO BASIN RESULTS

### Sacramento River at Shasta Dam

#### *Headwaters*

Four headwater reservoirs were modeled above Shasta (Lake Britton, Pit #6, Pit #7, and McCloud Reservoir). The starting storage for each of these reservoirs began near gross pool and all spilled heavily during simulations of each of the seven synthetic exceedence frequency events. The combined influence of these reservoirs on attenuating flood volumes was negligible.

#### *Lower Basin*

Shasta has 1.3 million acre-feet of flood control space and operates for the Sacramento River at Keswick (79,000 cfs) and Bend Bridge (100,000 cfs). Between Keswick and Bend Bridge there are several unregulated tributaries that generate significant inflows to the Sacramento mainstem. The influence of these tributaries is reflected in Shasta operations when Shasta is forced to lower releases while storage and inflow are increasing and flows are exceeding downstream operational limits. According to model simulations, Shasta offers protection to downstream areas for events occurring slightly more frequent than a 1-percent chance exceedence event.

### Feather River at Oroville Dam

#### *Headwaters*

The reservoir system modeled above Oroville included 9 headwater reservoirs (Mountain Meadows, Almanor, Butt Valley, Antelope, Bucks Storage, Lake Davis, Frenchman, Little Grass Valley, and Sly Creek) with a combined gross pool storage of 1.8 million acre-feet. Nearly 400,000 acre-feet of this storage is vacant and active at the start of the flood simulations. The effects of the headwaters, while significant for all seven synthetic exceedence frequency events, were limited by the amount of natural flow regulated. Though only 20 percent of the full-basin natural flow hydrograph for the Feather River at Oroville Dam was routed through headwater reservoirs, average peak inflows to Oroville were reduced by 12.4 percent and 310,000 acre-feet (average) was captured by the headwater facilities during the simulation of 1-, 0.5-, and 0.2-percent chance exceedence events.

#### *Lower Basin*

Oroville Dam has a maximum flood control space of 750,000 acre-feet and operates for several locations within the Feather River basin, including points below the confluence of the Yuba and Bear rivers. Due to the release schedule, the presence of gated spillways on Oroville and New Bullards Bar (Yuba River), and the number of points and related tributaries, the Feather River system was among the most complex tributaries to model.

In the model, emergency releases (gated releases based on modeled ESRD criteria) at Oroville Dam tended to begin several hours prior to those computed during manual routings. Through the course of the routings, HEC-5 simulations tended to increase releases more slowly than rates observed in manual computations. However, peak outflows ended in good agreement.

Model results show that Oroville Dam is capable of routing the 1-pecent chance exceedence event with a maximum storage of 3.4 million acre-feet (150,000 acre-feet below gross pool).

### Yuba River above Marysville

The Yuba River system is unique in that the headwater reservoirs do not regulate watershed area above a flood damage reduction project. There are seven reservoirs above the City of Marysville. Six are included in the headwaters model (4 on the Middle and South Forks of the Yuba and 1 each on Deer and Dry Creeks). The only lower basin reservoir is New Bullards Bar, which is also the only reservoir above Marysville with flood control space. New Bullards Bar regulates the North Fork of the Yuba, which is otherwise unregulated. Its releases are influenced by the 6 headwater reservoirs through operational points located below the confluence of the regulated headwater sources.

#### *Headwaters*

The 6 headwater reservoirs above Marysville (Jackson Meadows, Bowman, Fordyce, Spaulding, Scotts Flat, and Merle Collins) have a combined gross pool storage of approximately 320,000 acre-feet. According to the starting storages, 90,000 acre-feet are vacant at the start of the simulations. Most of this storage is available in the 4 reservoirs that regulate the Middle and South Forks of the Yuba River.

#### *Lower Basin*

New Bullards Bar has 170,000 acre-feet of flood space and operates for several locations within the Yuba and Feather river basins. In accordance with the Water Control Manual, New Bullards Bar cuts back on releases when flows in the Feather River are high to assure that flows at the Yuba River’s confluence with the Feather River do not exceed 300,000 cfs. This operation is performed despite the lower level of protection provided by New Bullards Bar (in comparison to Oroville), which, according to model results, is just below the 1-percent chance exceedence level.

New Bullards Bar also has a gated spillway. There were a few hours of releases above the objective flow at the dam (50,000 cfs) during simulations of the 4-percent chance exceedence event. These are not supported by manual routings, but are minor considering the complexities of the Feather -Yuba system.

### American River above Folsom Dam

#### *Headwaters*

Five headwater reservoirs were modeled (French Meadows, Hell Hole, Loon Lake, Union Valley, and Ice House). These reservoirs have a combined gross pool storage of 660,000 acre-feet, of which 200,000 acre-feet remains vacant at the start of the flood simulations. Unlike many of the other basins, vacant storage was distributed proportionally amongst the American

River headwater reservoirs. Facilities were all filled to between 54 and 85 percent of capacity. This balanced situation is reflected in simulations where only Union Valley reservoir, which receives a higher percentage of natural flow than the other four, spilled prior to the onset of the 1-percent chance exceedence event (and even while spilling, Union Valley reservoir significantly altered the flood hydrograph through surcharge storage). The combined effects of the headwater reservoirs, despite regulating only 14 percent of the full natural flow into Folsom Dam, reduced the peak inflow by an average of 10.4 percent and captured an average of 165,000 acre-feet during the critical 1-,
0.5-, and 0.2-percent chance exceedence simulations.

#### *Lower Basin*

According to the Water Control Diagram used in real-time operations, Folsom Reservoir has a maximum flood pool of 670,000 acre-feet. Folsom Dam does have a credit space agreement where up to 200,000 acre-feet of flood storage can be provided by a combination of available space in French Meadows, Hell Hole, and Union Valley reservoirs. All simulations of Folsom Dam were performed using outlet ratings that have been designed, but not yet implemented, by the Folsom Modifications portion of the ongoing American River Project. This aspect of the project has been authorized and is part of the future without-project conditions of the Comprehensive Study.

Gate operations at Folsom Dam were simulated with maximum releases capped at 160,000 cfs until a pool elevation of 470 feet was reached. Transitions from the design channel capacity of 115,000 cfs to 160,000 cfs were controlled by standard gate criteria of HEC-5. During the annual 1-percent chance exceedence event, these criteria briefly activated transitional flows before required by the ESRD. Although this led to a peak outflow slightly larger than 115,000 cfs, manual routings confirmed that Folsom Dam offers downstream areas a level of protection for the occurrence of events between a 1- and 0.5-percent chance exceedence. Comparisons of Comprehensive Study simulations and routings performed for the Folsom Modifications Study show simulated outflow hydrographs are consistent in magnitude and form. HEC-5 results display slightly lower peak outflows for the 0.5- and 0.2-percent chance exceedence events. This may be due to the detailed modeling of headwater reservoirs performed in this study.

## SAN JOAQUIN BASIN RESULTS

### Stanislaus River above Tulloch Dam

#### *Headwaters*

Three headwater reservoirs were modeled in the upper Stanislaus basin (New Spicer Meadows, Beardsley, and Donnells). The combined gross pool storage of these facilities is 320,000 acre-feet and, according to the starting storages, most of this space (170,000 acre-feet) is available in the rain flood season. New Spicer Meadows is a high elevation reservoir that regulates a small fraction of the natural flows in the Stanislaus watershed. This reservoir is primarily operated to fill during the snowmelt runoff and is relatively inactive during the winter months. New Spicer

Meadows did not spill during simulations of any of the seven synthetic exceedence frequency events.

Beardsley and Donnells regulate the Middle Fork of the Stanislaus River. Donnells is located upstream of Beardsley and regulates 11 percent of the total natural flow. Beardsley further regulates that 11 percent and an additional 14 percent, which enters the Middle Fork between the two reservoirs. Due to this substantial portion of total natural flow, reservoir size, operations, and available storage, Beardsley spills in all events occurring less frequently than the 50-percent chance exceedence event. Donnells closely follows suit, spilling in all events more severe than the 4-percent chance exceedence event. The combined effects of these reservoirs reduced the peak inflow by an average of 21.6 percent and captured an average of 95,000 acre-feet during simulations of the critical 1-, 0.5-, and 0.2-percent chance exceedence events.

#### *Lower Basin*

New Melones Reservoir has 450,000 acre-feet of flood space and an ungated spillway. Tulloch Reservoir, located just downstream of New Melones, contains only 10,000 acre-feet of flood space. The size discrepancy between the two reservoirs was evident in initial basin simulations. Releases from New Melones tended to quickly fill the smaller flood space at Tulloch reservoir. HEC-5 interpreted this as a danger and adjusted releases at both facilities to allow Tulloch reservoir to vacate the space. When Tulloch returned to the bottom of the flood pool, the cycle was repeated. To stabilize release, Tulloch was modeled as a flow-through reservoir. In this case, New Melones essentially looked past Tulloch to operate for downstream channel capacity. This helped to smooth out the operations, but even with the flow-through reservoir option, Tulloch and New Melones simulations have difficulties operating for local flows. During simulations, New Melones reservoir does not exceed downstream criteria until the simulation of a 0.5-percent chance exceedence event. Due mainly to significant local inflow between New Melones and Tulloch and in part to model dynamics, channel capacity below Tulloch Reservoir is exceeded during simulation of the 1-percent chance exceedence event.

### Tuolumne River above Don Pedro Dam

#### *Headwaters*

The 3 headwater reservoirs modeled above Don Pedro Reservoir are Hetch Hetchy, Cherry Valley, and Lake Eleanor. These reservoirs are an important source of water for the City of San Francisco; they are operated first for water supply and then for hydropower. Releases are also made to evacuate water while maintaining downstream flows below levels that could impair power generation and damage infrastructure located within the river channel. In this sense, these reservoirs follow operation criteria that mimic flood damage reduction criteria. Their combined gross pool storage is 630,000 acre-feet, of which 160,000 acre-feet are vacant at the start of the model simulations. Hetch Hetchy and Cherry Valley contain most of these capacities; each is over 10 times as large as Lake Eleanor.

These reservoirs regulate 40 percent of the Tuolumne River's natural flow at Don Pedro. Cherry Valley is a relatively large reservoir with respect to the percentage of natural flow it regulates (12 percent) and maintained low release levels throughout the simulations. Hetch Hetchy is similar in size to Cherry Valley, but experiences larger inflows (20 percent of Don Pedro natural flow).

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

Hetch Hetchy spilled during the simulation of the 1-percent chance exceedence event and all less frequently occurring events. Diversions into the Hetch Hetchy aqueduct were set at a constant rate of 110 cfs for simulation of all seven synthetic exceedence frequencies. The combined effects of these reservoirs reduced the peak inflow by an average of 23.9 percent and captured an average of 80,000 acre-feet during simulations of the more critical 4-, 2-, and 1-percent chance exceedence events.

#### *Lower Basin*

Don Pedro Reservoir has 340,000 acre-feet of flood space and provides flood protection to downstream areas including the City of Modesto. At Modesto, Dry Creek, which provides unregulated local flow, joins the Tuolumne River. Don Pedro Dam releases are operated to keep flows below the Dry Creek confluence within channel capacity limits of 9,000 cfs.

Don Pedro has a gated spillway. In accordance with the ESRD, maximum releases were capped at 9,000 cfs until pool elevation exceeded 830 feet during all simulations. Simulation results showed good agreement with manual routings and indicated that Don Pedro will spill in all events more severe than the simulated annual 4-percent chance exceedence event.

### Merced River above New Exchequer Dam

#### *Headwaters*

The upper Merced River Basin is unregulated; no reservoirs were modeled.

#### *Lower Basin*

New Exchequer Dam has 350,000 acre-feet of flood space, a gated spillway, and operates for one downstream point, the Merced River at Cressey. Dry Creek joins with Merced flows just above this location. Modeling this reservoir was straightforward. The ESRD for the project closely paralleled the general case HEC-5 was designed to model. New Exchequer Dam spilled in all simulations occurring less frequently than the simulated annual 4-percent chance exceedence event.

### San Joaquin River above Friant Dam

#### *Headwaters*

The Upper San Joaquin is among one the most heavily regulated basins within the study area. Seven headwater reservoirs, which regulate 75 percent of the natural flow at Friant, were included in the model (Edison, Florence, Mammoth Pool, Huntington, Shaver, Bass Lake, and Redinger). The combined gross pool storage is 590,000 acre-feet, of which 310,000 acre-feet are vacant at the start of model simulations.

The combination of number of facilities, available storage, methods of operation, and percentage of regulated natural flow proved to be very influential in reshaping the natural flood hydrograph at Friant Dam. In fact, the hydrology in the Upper San Joaquin River was effected more than that of any other headwater basin. Peak inflows were reduced by an average of 51.3 percent for all events and an average of 123,000 acre-feet was captured during simulation of the more critical 4-, 2-, and 1-percent chance exceedence events.

#### *Lower Basin*

Friant Dam has 170,000 acre-feet of flood space. There is a credit space agreement established that relates the top of conservation at Friant Dam to concurrent storages in Mammoth Pool. As much as 85,000 acre-feet of required flood space may be transferred. Friant operates for downstream locations below the Little Dry Creek confluence and at Mendota. Simulations perform very well for criteria below Little Dry Creek. This accuracy is not apparent for the Mendota location, which is located further downstream, below a large diversion and the confluence of another significant tributary. Discussion of Friant Dam's operations for Mendota is speculative, but difficulties are likely created by the distance and travel time of the site from Friant Dam and the model's simulation of the Chowchilla Diversion structure.

Like New Exchequer Dam, Friant Dam has a gated spillway with operational criteria that closely parallel the general case HEC-5 was designed to model. Simulation results were stable and accurate. The reservoir spilled in all simulations occurring less frequently than the 4-percent chance exceedence event.

### Kings River above Pine Flat Dam

#### *Headwaters*

There are two headwater reservoirs of significant size above Pine Flat Dam (Courtright and Wishon). Their combined gross pool storage is roughly 250,000 acre-feet, of which 150,000 acre-feet are vacant at the start of model simulations. Courtright and Wishon occur in series high on the North Fork of the Upper Kings River and regulate only 10 percent of the natural basin flows. These facilities are unique in that there is a pump system capable of sending large flows from Wishon upslope to Courtright. This pump system is typically operated in times of low power demand so water can be rerun through power generation facilities during times of high demand. As operations try to avoid spilling water from Wishon when there is space available in Courtright (this would represent lost generation potential), the pump-back system essentially balances the pools. Instead of modeling this relationship in HEC-5, the storages and inflows of Courtright and Wishon were consolidated into a single reservoir. The outlet and spillway works of Wishon, the lower reservoir, were applied to the combined reservoir because outlet capabilities, in conjunction with operational decisions, determine flow releases to downstream areas. Therefore, any combined reservoir should reflect release capabilities of the individual reservoir furthest downstream in order to model realistic downstream conditions.

The effects of the combined reservoir were noticeable, but tempered by the low percentage of regulation. Peak inflows were reduced by an average of 9.5 percent and an average of 22,000 acre-feet of flood volume was captured during simulation of the more critical 1-, 0.5-, and 0.2-percent chance exceedence events. The combined reservoir did not spill during any of the events.

### *Lower Basin*

Pine Flat Dam has 475,000 acre-feet of flood control space. There is a credit space agreement that can raise the top of conservation at Pine Flat Dam by the concurrent storage available in Courtright and Wishon reservoirs to less than 20,000 acre-feet. Pine Flat has one operational location, Kings River at the Friant-Kern Canal. Between the dam site and the canal, Mill and Hughes creeks, two local tributaries, join the Kings River. These flows were properly accounted for in the HEC-5 model simulations.

Below the Friant-Kern Canal, the Kings River enters into a system of distributaries that split flood flows to the San Joaquin Basin through Kings River North, and to the Tulare Basin through Kings River South. In accordance with the Water Control Manual, the first 4,750 cfs of simulated flood releases are sent North and the next 3,200 are diverted South. Within the model, any flood flows in excess of 7,950 cfs are divided equally between the North and South.

Pine Flat Dam has a gated spillway and simulations did not calibrate with the ESRD as well as those for most other reservoirs. In the model, emergency releases tended to begin several hours prior to those computed through manual routings. In spite of this, simulated releases during events that require gated spillway flows (0.5- and 0.2-percent chance exceedence events) were close to manual routings. The reservoir spilled in all simulations higher than the annual 1-percent chance exceedence event.

# CHAPTER VI

# LOWER BASIN RESERVOIR RE-OPERATIONS

## OVERVIEW

Re-operation of lower basin flood damage reduction reservoirs were performed as an analysis of existing flood operations in both the Sacramento and San Joaquin river basins. Reservoir re-operations were modeled using the existing baseline HEC-5 architecture developed and presented in Chapter III. In order to gain a better understanding of the study area and answer questions posed by the team, local and regional interests and agencies, the models were used to perform a number of evaluations. While countless evaluations are possible, those that have been conducted to date were designed to illustrate a broad range of potential re-operational changes. Within this document these evaluations are referred to as "alternatives." The re-operation alternative scenarios were executed using HEC-5, by modifying parameter values of available flood control space and objective flow values. Three lower basin reservoir re-operation analyses are discussed herein: storage and objective release grid analysis, reservoir reoperation alternative scenarios, and transitory floodplain storage analysis. Tables and figures summarizing the simulation results from these analyses are presented within this chapter and in Attachments C.3 and C.4.

The grid analysis provides information on how incremental changes to an individual reservoir's flood control storage and/or objective release affect the ability to manage various frequencies various flood events. The alternative scenarios were developed for use as planning tools in assessing the performance of various basin-wide conceptual plans. Parameters of available flood control space and objective flow values were varied, models executed, and output tabulated for events of 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedences. Unlike the grid analysis, these alternatives provide a system-wide perspective and analysis at multiple index locations on both the mainstems of the Sacramento and San Joaquin rivers and their tributaries. Performance of flood damage reduction reservoirs were simulated with their respective tributary specific, synthetic flood centerings developed in the *Synthetic Hydrology Technical Documentation*. Index locations were used as a point of reference in comparison of attenuated flow volumes. Last, the floodplain storage analysis evaluates the effectiveness of combinations of several representative off-stream storage areas in reducing peak flows in the mainstem of the San Joaquin River.

## GRID ANALYSIS

Alternatives analysis is a learning phase in the planning process. Systems are assessed from different viewpoints and new management concepts are tested. One of the first investigations tested how changes in objective release (maximum flow rate below reservoirs as established in current operational guidelines) and amount of reservoir storage dedicated to flood reduction would influence levels of protection and outflows in accordance with existing reservoir operating criteria. Both variables were changed incrementally (individually and in combination) for a range of values and simulated with the baseline HEC-5 models constructed during the without project phase. All other system constraints were held consistent with baseline (without project) conditions.

Results were tabulated with the incremental objective flows in columns and the flood space in rows, creating a matrix format and leading to the title "Grid Analysis." Grid analyses were performed for Shasta, Black Butte, Oroville, New Bullard's Bar, New Melones, Don Pedro, New Exchequer, Buchanan, Hidden, Friant, and Pine Flat reservoirs. The rest of this section details the methodology, a sample grid analysis, and summary results for all analyses.

## Methodology

### *Setting the Grids*

Ranges were chosen based on the following criteria: 1) Assess a wide range without violating other system constraints (i.e., minimum pool restrictions, downstream channel and operational limitations); 2) Increase and decrease both variables; 3) When no constraints are identified, use twice the flood storage and objective flow as upper bounds for variable increase; and 4) Test values that have been mentioned by local and/or regional interests, agencies, and other studies as constraints or possible alternatives.

### *Hydrologic Input to the Simulations*

Grid analyses focused on reservoir operations and all simulations were performed with tributary specific centerings (see Appendix B, Chapter III). System perspectives, including study of changes in available flood space and objective flows on mainstem areas, are discussed later in this chapter.

### *Maintaining Consistency with the Baseline*

Care was taken to assure that alternative simulations reflected only the changes made to flood storage and objective release. Two key parameters held consistent with the baseline were ramp up scenarios and gate operations. There were two primary types of ramp up scenarios (see Chapter III) for studied reservoirs. The first increased releases to maximum objective flows as a function of percent encroachment (percent of dedicated flood space filled with water). Here, relations of percent objective release to percent encroachment were held constant. Therefore, during simulations with increased flood storage, releases ramped up more conservatively than the baseline because it took more flood volume to encroach the pool to any specific percentage. While this reduced the efficiency of added storage, it was consistent with the baseline and logical from an operation perspective. The second ramp up scenario increased releases to objective flow limits as a function of the magnitude of flood inflows to the reservoir and percent encroachment. For these facilities, relationships between specified releases and reservoir inflow were held identical to the baseline until inflow rates triggered the maximum flood release, which was changed to match the alternative maximum objective flow from the grid. As in the first ramp up scenario, relations involving percent encroachment were held constant.

Gated operations required minor changes to incorporate alternative maximum objective releases. For example, emergency releases from spillway gates at Don Pedro Reservoir do not begin under baseline conditions until the water surface elevation within the reservoir exceeds a reservoir elevation of 830 feet above mean sea level. Until this elevation, releases never exceed 9,000 cfs, which is the maximum objective flow under baseline conditions. This relation was scripted into baseline gate operations and adjusted whenever an alternative objective flow was investigated. Changes in flood storage had no effect on gate operations, which began near the top of the flood storage regardless of flood pool size.

## Results and Discussion

Grid results for all frequencies and reservoirs are presented in Attachment C.3, Figures C.3-1 through C.3-11. This section discusses 1) the construction, simulation, and use of a sample analysis; and 2) review and use of all results in general.

### *Sample Grid*

Don Pedro Reservoir on the Tuolumne River has a baseline objective flow of 9,000 cfs and a maximum storage capacity of 2,030 thousand acre-feet (TAF) (340 TAF of which is dedicated control flood storage). Baseline simulations indicated that Don Pedro Reservoir exceeded objective flows in all events occurring less frequently than the 4-percent chance exceedence event (see Chapter V).

Since modeling results indicate Don Pedro Reservoir offers a relatively low level of protection to downstream areas, alternatives focused on increases to available flood storage and objective flows. The maximum increase in flood storage was 340 TAF (no minimum pool restrictions were violated). Channel capacities are restrictive in the lower Tuolumne River and flows greater than 15,000 cfs inundate infrastructure around the City of Modesto. The 15,000 cfs flow rate is also mentioned by other studies (*Tuolumne River Feasibility Study, USACE*) as the highest plausible increase to objective flows and was incorporated into the analysis as the maximum alternative flow.

To produce Don Pedro Reservoirs grid, simulations were performed for all seven synthetic exceedence frequency events (50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedence events) using the Tuolumne River centering. This tributary centering was originally prepared in the Synthetic Hydrology (see Appendix B) and routed through the HEC-5 headwater reservoirs model during baseline analyses. Results of the simulated 2-percent chance exceedence event are presented in Figure VI-1.

Simulations where peak reservoir releases did not exceed the maximum objective flow are shaded. Generally, flood releases less than or equal to the objective flow threshold cause minimal damage to downstream areas and the interface between shaded and non-shaded cells reflect combinations of flood storage and objective flows that safely pass the annual 2-percent chance exceedence event while exhausting the reservoir's capacity to reduce floods. Theoretically, this relation between operating parameters and the start of damaging flows is a smooth function that would pass near or through points on the grid interface of shaded and non-shaded cells. The optimal combination of change in available flood storage and change in objective flow can be estimated from the grid results as exemplified in Figure VI-1 or from graphical representations as shown in Figure VI-2, and presented in Attachment C.3.

**FIGURE VI-1 DON PEDRO RESERVOIR – TUOLUMNE RIVER, ANNUAL 2% CHANCE EXCEEDENCE EVENT**

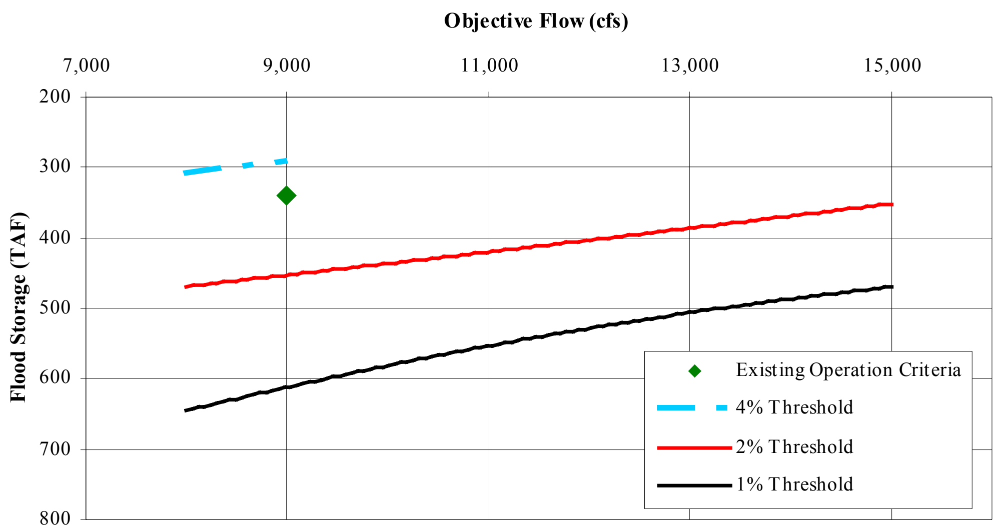
| **Key:** | Model Simulation |
|---|---|
| Peak flow - objective flow<br>*Percent encroached* | |
| Objective flow is not exceeded (shaded) | |

**Change in Objective Flow (cfs)** / **Change in Flood Storage (TAF)**

| | **-1,000** | **0** | **1,000** | **2,000** | **4,000** | **6,000** |
|---|---|---|---|---|---|---|
| **-50** | TUO-E01A<br>47,651<br>*107%* | TUO-E02A<br>42,587<br>*106%* | TUO-E03A<br>38,445<br>*106%* | TUO-E04A<br>35,403<br>*105%* | TUO-E05A<br>27,743<br>*104%* | TUO-E06A<br>19,932<br>*103%* |
| **0** | TUO-E07A<br>35,396<br>*104%* | **BASELINE**<br>**30,600**<br>***104%*** | TUO-E08A<br>25,951<br>*103%* | TUO-E09A<br>22,115<br>*103%* | TUO-E10A<br>11,660<br>*101%* | TUO-E11A<br>1,611<br>*100%* |
| **50** | TUO-E12A<br>21,973<br>*102%* | TUO-E13A<br>16,438<br>*101%* | TUO-E14A<br>12,383<br>*101%* | TUO-E15A<br>10,792<br>*101%* | TUO-E16A<br>0<br>*100%* | TUO-E17A<br>0<br>*91%* |
| **100** | TUO-E18A<br>14,578<br>*101%* | TUO-E19A<br>13,569<br>*101%* | TUO-E20A<br>10,540<br>*100%* | TUO-E21A<br>0<br>*99%* | TUO-E22A<br>0<br>*90%* | TUO-E23A<br>0<br>*82%* |
| **200** | TUO-E24A<br>0<br>*95%* | TUO-E25A<br>0<br>*91%* | TUO-E26A<br>0<br>*87%* | TUO-E27A<br>-175<br>*83%* | TUO-E28A<br>0<br>*76%* | TUO-E29A<br>0<br>*69%* |
| **340** | TUO-E30A<br>0<br>*78%* | TUO-E31A<br>0<br>*74%* | TUO-E32A<br>0<br>*71%* | TUO-E33A<br>-171<br>*68%* | TUO-E34A<br>-302<br>*62%* | TUO-E35A<br>-252<br>*57%* |

Amount of flow above objective at peak reservoir release and the percent encroached at peak storage for the annual 2-percent chance exceedence flood event. Don Pedro is currently operated to maintain flows below 9,000 cfs at Modesto and has a maximum flood pool of 340 TAF.

**FIGURE VI-2 SAMPLE GRID ANALYSIS**




*Curves delineate combinations of flood storage and objective flows that would pass a specified frequency event while exhausting the capabilities of the flood damage reduction reservoir. These curves are estimated through visual inspection of the grid results. Use of these values in plan preparation should be verified through simulations and manual routings.*

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

### *Review of Results*

The grids developed for Shasta, Oroville, New Bullards Bar, and Friant dam revealed simulated releases in excess of objective flow criteria, prior to those that would be required by standard operating procedures outlined within the respective Water Control Manuals. These releases were associated with the start of emergency gate releases during HEC-5 simulations; similar release dynamics were noted during baseline modeling (see Chapter V). In these cases, definition of the damage – non-damage interface was verified manually for all grid points. Grid cells were shaded where releases in excess of established objective flow criteria were above and beyond those that would occur according to actual operational mechanisms. All other grids displayed consistent results in agreement with baseline simulations and standard operations set forth in Water Control Manuals.

## RESERVOIR RE-OPERATION WITHIN THE SACRAMENTO AND SAN JOAQUIN RIVER BASINS

The grid analysis previously described provides an assessment of how changes to a reservoir's objective flow releases and flood control storage influence the level of flood protection along tributaries of both the Sacramento and San Joaquin rivers. Using the grids as a guide, a variety of specific alternative scenarios were modeled using the Sacramento and San Joaquin river HEC-5 flood control simulation models (Tables VI-1 and VI-2).

The primary purpose of the lower basin alternative scenarios was to examine the effects that changes to selected reservoir re-operation criteria would have on peak flows and volumes in both the tributaries and mainstem of the Sacramento and San Joaquin rivers. Unlike the grids, many of the alternative scenarios evaluate changes in objective flow and available flood control space for more than one reservoir at a time and simulate these analyses with a variety of storm runoff centering patterns. The majority of the alternative scenarios include changes to both a reservoir's objective releases and allocated flood control storage. However, a few alternatives examine other more detailed and difficult modifications. For example, forecast-based operations and increased dam height, as adopted from the American River Long Term Study, were modeled in the alternative scenario SAC-B04A.

Results from HEC-5 alternative scenarios were taken as input into the Sacramento and San Joaquin Basin UNET models to determine hydraulic impacts along the mainstem.

## TABLE VI-1

## ALTERNATIVE SCENARIO MODIFICATIONS
## SACRAMENTO RIVER BASIN

<table>
<tr><th colspan="2"></th><th>SAC-B01A</th><th>SAC-B02A</th><th>SAC-B03A</th><th>SAC-B04A</th></tr>
<tr><td rowspan="2">Shasta Dam and Reservoir</td><td>Flood Reservation</td><td>1,300 TAF</td><td></td><td></td><td></td></tr>
<tr><td>Objective Release</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Cottonwood Creek</td><td>Flood Reservation</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Objective Release</td><td></td><td>15,000 cfs</td><td></td><td></td></tr>
<tr><td rowspan="2">Oroville Dam and Reservoir</td><td>Flood Reservation</td><td>750 TAF</td><td></td><td rowspan="2">Incremental changes made to available storage and objective flow</td><td rowspan="2">Incremental changes made to available storage and objective flow</td></tr>
<tr><td>Objective Release</td><td></td><td></td></tr>
<tr><td rowspan="2">New Bullards Bar Dam and Reservoir</td><td>Flood Reservation</td><td></td><td></td><td rowspan="2">Incremental changes made to available storage and objective flow</td><td></td></tr>
<tr><td>Objective Release</td><td></td><td></td><td></td></tr>
</table>

## TABLE VI-2

## ALTERNATIVE SCENARIO MODIFICATIONS
## JOAQUIN RIVER BASIN

| | | SJQ-B01A | SJQ-B02A | SJQ-B03A | SJQ-B04A | SJQ-B05A | SJQ-B06A | SJQ-B07A |
|---|---|---|---|---|---|---|---|---|
| ***Friant Dam and Reservoir*** | Flood Reservation | **170 TAF** | **100 TAF** | | **50 TAF** | **100 TAF** | | |
| | Objective Release | | | | **4,000 cfs** | | **8,000 cfs** | |
| ***New Exchequer Dam*** | Flood Reservation | | **50 TAF** | | | **50 TAF** | | |
| | Objective Release | | | | **1,000 cfs** | | | **2,000 cfs** |
| ***Don Pedro Dam and Reservoir*** | Flood Reservation | **340 TAF** | **100 TAF** | | | **200 TAF** | | |
| | Objective Release | | **2,000 cfs** | **6,000 cfs** | **6,000 cfs** | | | |

*Note: Values represent increases to existing criteria.*

### Alternative Scenario SAC-B01A

Comparison of the baseline and alternative simulation results indicate little to no attenuation of the peak flow maxima and peak volume within northern portions of the Sacramento River, with the exception of those occurring during the simulated 0.5- and 0.2-percent chance exceedence events. The maximum attenuation of peak volumes occurs during the simulation of an annual 0.2-percent chance exceedence event. The effects of additional storage in Shasta Reservoir is noticed along the Sacramento River for the more extreme events because of Shasta's capability to cutback on large release volumes. For more frequent events (those occurring more frequently than the simulated 1-percent chance exceedence), the lack of attenuated flow volume is due to the large contributions of unregulated local flow generated upstream of Ord Ferry.

Some irregularities may be observed within the tables. For example, at Bend Bridge during the simulation of an annual 4-percent chance exceedence event centered at Oroville Dam, there is no indicated reduction in peak flow maxima, but results indicate an attenuated peak volume of 179,463 acre-feet. Inconsistencies such as this are attributed to hydrograph shape. Both the resultant baseline and alternative hydrographs maintain nearly similar peak flow values, but exhibit a calculated peak flow reduction with the hydrograph shapes indicating different associated volumes.

Index locations situated along the southern reach of the Sacramento River (i.e., Verona and Sacramento) are located downstream of the Feather River confluence. Peak flows and volumes are subsequently affected by storage increases at both Oroville and Shasta reservoirs. Since simulations of this alternative indicate minimal attenuation along the Sacramento River upstream of its confluence with the Feather River for events occurring more frequently than a 1-percent chance exceedence event, it can be concluded that Oroville is responsible for attenuating the majority of peak flow at Verona and Sacramento for these events. However, for the larger events (i.e., 0.5- and 0.2-percent chance exceedence events) both Shasta and Oroville contribute substantially to the attenuated flows at Verona and Sacramento.

### Alternative Scenario SAC-B02A

Alternative SAC-B02A simulates the effect of restricting the contribution of Cottonwood Creek flows into the Sacramento River to a maximum of 15,000 cfs. The purpose of this alternative is to observe the effect that a hypothetical dam on Cottonwood Creek might have on downstream peak flow maxima and flood volumes. Cottonwood Creek was chosen because it remains one of the largest, generally unregulated tributaries to the Sacramento River. The flow adjustments of this alternative were made to the existing HEC-5 DSS input file through mathematical manipulations using the USACE's DSSMATH utility program. Modeling a hypothetical dam within HEC-5 may provide a more accurate approach, however this method demands a much more detailed modeling effort in that specific physical design characteristics of the dam itself need to be known. Through the chosen method, the simulated effect of regulated flow contributions of Cottonwood Creek on downstream locations can still be observed.

Because there were no flood management reoperations associated with Oroville Dam in this alternative, all values representative of the index location "Oroville" are zero (Table C.4-2). This reservoir will continue to operate as it had within the baseline simulation results. Reduction in peak maxima at index locations along the northern reach of the Sacramento River, occur during events greater in magnitude than the 1-percent chance exceedence event for all storm-runoff centerings. Locations lower in the basin, such as Verona and Sacramento, experience maximum percent peak reductions during events generally less than or equal to the 4-percent chance exceedence event, though all percent peak reductions are only within a few percentage points of one another at these southerly locations. Percent peak reductions in the northerly reaches of the Sacramento River are much higher and more variable. In the most northern reaches of the Sacramento River, simulated peak reductions range from 15 to 35 percent, but only 0.4 to 3.5 percent in the southern reaches. It can be surmised that restricting the flow contributions of Cottonwood Creek to 15,000 cfs has a significant impact on peak flow attenuation for locations above Ord Ferry. However, benefits may be minimal at downstream locations such as Verona and Sacramento.

**Alternative Scenario SAC-B03A**

The purpose of alternative SAC-B03A was to restrict flows in the Feather River downstream of its confluence with the Yuba River (at Shanghi Bend) to 230,000 cfs for all seven synthetic exceedence frequencies up to and including the annual 1-percent chance exceedence event. Because there was no specific requirement for additional flood control space specified for any particular reservoir in the SAC-B03A problem definition, the analysis approach was somewhat different from the other alternatives: it involved increasing flood storage space incrementally in Oroville and New Bullards Bar reservoirs (the contributing lower basin reservoirs) and reducing index gage operating criteria. Both the Feather River and Yuba River storm runoff centerings were analyzed for this alternative, since they generated the most extreme stream flow conditions in the upper Feather and Yuba river system.

Two main adjustments had to be made to the baseline HEC-5 models for this alternative: adjusting release operating criteria and increasing available flood control storage space. The first parameter adjusted was the reservoir's downstream release operating criteria. Both New Bullards Bar and Oroville reservoirs operate for several independent and common index gages. This makes the Feather/Yuba river system unique in that its operations are more comparable to a true systematic or coordinated effort, and provide a complexity of operation beyond that of other systems, which typically operate independently for a single index location. Current operational requirements for Oroville Reservoir are to keep flows at or below the following values along the Feather River: 150,000 cfs at Gridley, 180,000 cfs upstream of its confluence with the Yuba River (at Yuba City), 300,000 cfs downstream of its confluence with the Yuba River (at Shanghi Bend), and 320,000 cfs at Nicolaus. Operations at New Bullards Bar Reservoir are dependent on flow conditions both in the Yuba and Feather rivers. When flows in the Feather River upstream of its confluence with the Yuba are at or above 180,000 cfs, New Bullards Bar Reservoir must operate so that flows are kept at or below 120,000 cfs on the Yuba River at the City of Marysville. However, if flows in the Feather River upstream of its confluence with the Yuba River are lower than 180,000 cfs, New Bullards Bar releases may be increased, provided that flows at Marysville do not exceed 180,000 cfs. Since this alternative posed a reduction in flows at Shanghi Bend from 300,000 cfs to 230,000 cfs, all other index gage operational points had to be adjusted. These adjustments are shown below in Table C.4-3.

The second parameter that was adjusted in the HEC-5 models was the available flood control space. It was increased incrementally within the HEC-5 input files by lowering the top of conservation values of both reservoirs. Increases in available flood storage in each reservoir were modeled both independently and in conjunction with one another, since the operational procedures of New Bullards Bar Reservoir are affected by flow rates in the Feather River (at Yuba City). After initial simulations, it was evident that increases to the available flood control space in New Bullards Bar Reservoir had little effect on attenuating downstream peak flows in the Feather River. This is because New Bullards Bar Reservoir regulates less than 40 percent of the Yuba River drainage basin. For this reason, the primary focus of this alternative was changes in the amount of available flood control space in Oroville Reservoir. Table C.4-3 exhibits the resultant peak flow maxima that the models generated at various operating locations along the Feather and Yuba rivers for five increases to flood storage in Oroville Reservoir.

Peak flows at Shanghi Bend exceeded the alternative's operational criteria of 230,000 cfs, for the 1-percent chance exceedence event, for all model simulations. Peak flows are shown to generally decrease at Shanghi Bend as flood storage in Oroville Reservoir is increased. The largest reduction in peak maxima occurs when flood control space is increased by 200,000 acre-feet when an annual 1-percent chance exceedence runoff event is centered at Oroville Dam. This percent peak reduction diminishes with increasing flood storage.

**Alternative Scenario SAC-B04A**

In this alternative, two major changes to the Sacramento lower basin HEC-5 baseline model were made in order to incorporate: 1) some of the changes being proposed by the American River Watershed Investigation (ARWI) to Folsom Dam, and 2) the results of alternative run SAC-B03A that added 200 TAF of flood space to Oroville Reservoir. The Folsom Dam changes that were incorporated into the HEC-5 model came from two of the three major components stemming from the ARWI: The American River Long-Term Study and the Folsom Dam Modifications Project. The main components of the Folsom Dam Modifications Project include modified outlets and ramp-up criteria, increased surcharge storage, and advanced release operations based on precipitation and runoff forecasts. The American River Long-Term Study is examining how to increase flood protection along the American River by means of enlarging Folsom Dam. All of the main components of the Folsom Dam Modifications Project, as well as raising the dam to an elevation of 482 feet (an alternative being examined by the American River Long-Term Study), were included in this modeling effort.

The ARWI is using two models to perform Folsom Reservoir routings: the Reservoir Release Forecast Model (RRFM) developed by Utah State University and an accompanying Excel spreadsheet model. Some of the operating criteria proposed by the Folsom Dam projects are not programmed into RRFM; hence, reservoir outflows had to be hard-coded by hand prior to simulation of the model. The spreadsheet model, however, includes some of the modified operating rules that the RRFM does not, such as pre-release operations and the 60-percent rule (Table VI-3). For these reasons, the spreadsheet model was selected to simulate operations of Folsom Dam in this application of the Comprehensive Study hydrology.

Four of the Sacramento Basin synthetic storm runoff centerings (Ord Ferry, Sacramento, Feather River, and American River) were routed through the reservoir model. The Ord Ferry and Sacramento centerings were chosen because they are mainstem centerings, which stress the entire basin. The Feather River and American River tributary centerings stress individual tributary systems, but are not widespread enough to produce runoff volumes typical of a basin-wide event. Since this alternative includes the re-operation of both Folsom and Oroville dams, their associated tributary centerings were chosen to simulate extreme flood events along the Feather and American Rivers.

The ARWI has examined many scenarios with different assumptions and operating criteria. This study involved modeling operating criteria that are being examined by the ARWI, but were executed to remain consistent with assumptions developed by the Comprehensive Study. The similarities and differences between two ARWI scenarios and the modeling efforts associated with this study are described in Table VI-3.

**TABLE VI-3**

**ASSUMPTIONS AND OPERATIONAL CONDITIONS FOR FOLSOM DAM**

| Factor | American River Watershed Investigation (Base Case) | American River Watershed Investigation (Min Case) | Comprehensive Study |
|---|---|---|---|
| ***Flood waves modeled*** | 1 (main wave only) | | 6 (entire 30 day storm) |
| ***Synthetic hydrograph wave shape*** | Based on 1980 PMF | | Based on 1997 event |
| ***Starting storage*** | 277,000 ac-ft | 337,000 ac-ft | 377,000 ac-ft |
| ***Initial upstream reservoir space*** | 0 ac-ft | 150,000 ac-ft | 167,000 ac-ft |
| ***Initial top of conservation with credit space adjustments*** | 377,000 ac-ft | 527,000 ac-ft | 544,000 ac-ft |
| ***Headwater routing effects*** | None | Reduce unregulated volume by 14% of the 3-day volume (peak flow reductions range from 0-14%) | Use regulated inflow to Folsom from HEC-5 headwaters model (peak flow reductions range from 9-13%) |
| ***Outlet works operation*** | 100% | | |
| ***Minimum flow*** | 8,000 cfs (max power) | | 1,500 cfs (minimum release) |
| ***Rate of change of release on rising limb of flood wave*** | 5,000 cfs/hr to 25,000 cfs inflow<br>10,000 cfs/hr above 25,000 cfs inflow | | |
| ***Outflows from Folsom when inflows are < 25,000 cfs*** | 4-hour response time matching outflow to inflow | | |
| ***Outflow from Folsom when inflows are > 25,000 cfs*** | 60% Rule: Outflow is limited to 60% of inflow until the actual inflow exceeds 150,000 cfs | | |
| ***Rate of change of release on falling limb of flood wave*** | 5,000 cfs/hr until outflow reaches 20,000 cfs<br>Use USBR criteria when outflows are less than 20,000 cfs | | |
| ***Pre-release operation*** | Assume additional 100,000 ac-ft of flood control storage in Folsom at beginning of main wave (assumption based on previously modeled pre-release operation scenarios) | Assume additional 190,000 ac-ft of flood control storage in Folsom at beginning of main wave (assumption based on previously modeled pre-release operation scenarios) | Begin ramping up at a rate of 20,000 cfs/hr to 115,000 cfs 72 hrs prior to first forecasted inflow of 300,000 cfs or more |

The main differences between the ARWI scenarios and the Comprehensive Study are the assumptions associated with the influence of headwater reservoirs in providing flood protection. Modeling of SAC-B04A used output from the HEC-5 headwaters model developed for the Comprehensive Study. The Folsom credit space computations were generated by hourly storage values of all five headwater reservoirs modeled. Peak flow attenuation of Folsom inflow is also a product of the HEC-5 headwater model output. Peak reductions of inflow into Folsom range from 9 to 13 percent, depending on the event (Table VI-4). The ARWI baseline case assumes no attenuation due to headwater regulation and therefore no credit space adjustments for potential upstream storage allocations. However, the ARWI Minimum Case does assume a 14-percent, 3-day volume reduction and 150,000 acre-feet of upstream credit space. This equates to peak flow reduction of 0 to 14 percent, depending on the exceedence event being simulated. Therefore, the ARWI Minimum Case is more representative of the Comprehensive Study information. Other differences between the Comprehensive Study and the ARWI modeling parameters that affect the output results include: hydrograph shape, storm duration, and pre-release operating assumptions. Keeping these differences in mind, comparison of peak outflows between the ARWI minimum case and SAC-B04A are in good agreement (Table VI-4).

**TABLE VI-4**

**PEAK FLOW COMPARISONS FOR FOLSOM DAM**

| Percent Chance Exceedence | **Peak Inflows (cfs)** | | | **Percent Differences** | |
|---|---|---|---|---|---|
| | ARWI Base Case | ARWI Min Case | Comp Study | Base vs. Comp Study | Min vs. Comp Study |
| 4% | 207,410 | 178,370 | 196,408 | 5.6% | -9.2% |
| 2% | 274,860 | 236,380 | 258,555 | 6.3% | -8.6% |
| 1% | 353,540 | 304,040 | 329,258 | 7.4% | -7.7% |
| 0.5% | 444,570 | 408,320 | 409,934 | 8.4% | -0.4% |
| 0.2% | 585,930 | 585,930 | 536,703 | 9.2% | 9.2% |

| Percent Chance Exceedence | **Peak Inflows (cfs)** | | | **Percent Differences** | |
|---|---|---|---|---|---|
| | ARWI Base Case | ARWI Min Case | Comp Study | Base vs. Comp Study | Min vs. Comp Study |
| 4% | 115,000 | 115,000 | 115,000 | 0.0% | 0.0% |
| 2% | 115,000 | 115,000 | 115,000 | 0.0% | 0.0% |
| 1% | 115,000 | 115,000 | 116,814 | -1.6% | -1.6% |
| 0.5% | 122,570 | 115,000 | 119,689 | 2.4% | -3.9% |
| 0.2% | 528,380 | 498,860 | 485,040 | 8.9% | 2.8% |

**Alternative Scenario SJQ-B01A**

The results of scenario SJQ-B01A are presented in Table C.4-5. Comparison of the baseline peak flow maxima versus those generated through the simulation of this alternative show the largest percent peak flow reductions at each storm runoff centering generally occur at or nearest the two facilities modified in the simulation of this alternative (Friant and Don Pedro dams). During every flood runoff centering, with the exception of the one at Friant Dam, the largest percent peak flow reduction occurred at Don Pedro Dam during simulation of the 2-, 1-, 0.5-, and 0.2-percent chance annual exceedence events. This is due mostly to the large increase in available flood space in this facility suggested by this alternative. The largest reduction in peak flow maxima that occurred during the Friant Dam flood runoff centering occurred at Friant Dam. Reduction in peak discharges are noticeably smaller at mainstem locations, compared to the reduced peak regulated outflows of the flood control facilities themselves. This is attributed to the different conveyance capacities between the mainstem and its tributaries. Maximum releases from the flood damage reduction reservoirs were calculated at each facility with data obtained from simulating each synthetic flood runoff centering. Operations of both Friant and Don Pedro dams are affected by objective flow criteria at downstream index gage locations. Friant releases are operated to keep flows at or below 8,000 cfs downstream of its confluence with Little Dry Creek and a maximum of 6,500 cfs at a control point below Mendota Dam. Operational releases at Don Pedro Dam are to be kept at or below 9,000 cfs just downstream of the Dry Creek confluence with the Tuolumne River. As can be observed in the reservoir simulation hydrographs in Attachment C.4, objective flows were exceeded by the 1-percent chance exceedence storm runoff event centered at Friant and a 0.5-percent chance exceedence storm runoff event centered at Don Pedro (Figures C.4-5c and C.4-5g). By comparison, objective flows modeled at baseline conditions were exceeded at Friant by an annual 4-percent chance exceedence event and at Don Pedro by an annual 2-percent chance exceedence event (Attachment C.1, Figures C.1-8c and C.1-12d).

Alternative SJQ-B01A did not involve the modeling of variations to the available flood storage, objective flow parameters, or any other operational changes at the New Exchequer flood control reservoir. This results in two effects observed during the analysis. First, the percent peak reduction and volume attenuated for all return periods at each synthetic storm centering at New Exchequer are zero. Second, the percent reductions in peak maxima during the more frequent synthetic exceedence frequencies are little to none for the Exchequer flood runoff centering at all other gage locations. Several calculated peak reduction values at Don Pedro Reservoir for several of the synthetic exceedence frequencies within the centering groups are also found to be zero. Peak reductions of zero values are appropriate in these instances only because the maximum peak flows for both the baseline and alternative are the same. Volumes attenuated, however, may be significant in magnitude and clearly present flood damage reduction benefits.

As previously mentioned, this alternative resulted in large percent peak reduction at the locations of the Friant and Don Pedro reservoirs, where the alternative modifications were applied. In contrast, this alternative analysis has less effect in peak flow reductions on the mainstem, especially when the flood centering is targeted over that mainstem basin. This can be observed during the Newman flood centering. During this centering, gage locations at Modesto, Maze Rd., and Vernalis experienced flow increases for all synthetic exceedence frequencies up to and including the simulated 4-percent chance exceedence runoff event.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

**Alternative Scenario SJQ-B02A**

The results of scenario SJQ-B02A are presented in Tables C.4-6a and C.4-6b. For each synthetic flood runoff centering, the maximum reduction in the resultant peak flow occurs between simulation of the annual 2-, 1-, 0.5-, and 0.2-percent chance exceedence events at each index gage location, depending on which storm runoff centering is analyzed. Effects of changes in peak discharges are generally smaller at mainstem locations, downstream of tributary contributions, compared to the reduced, peak regulated outflows of the flood control facilities. This is attributed, in part, to the different conveyance capacities between the mainstem and its tributaries. Volumes attenuated at each location, however, are incrementally higher within the mainstem, as would be expected. Flood control operations at Friant, New Exchequer, and Don Pedro dams are affected by objective flow criteria at downstream index gage locations. Friant releases are operated to keep flows at or below 8,000 cfs downstream of its confluence with Little Dry Creek, and a maximum of 6,500 cfs at a control point below Mendota Dam. Flows from New Exchequer must be adjusted to allow for local flow contributions below the dam to avoid exceeding the channel capacity of 6,000 cfs downstream at Cressey, on the Merced River. Likewise, the modified Don Pedro releases for this alternative are operated to keep flows at or below 11,000 cfs (an increase of 2,000) just downstream of Dry Creek's confluence to the Tuolumne River. Because of the change in objective flow releases within the Tuolumne River, output data cannot be directly compared to the baseline modeling results. Direct benefits are noticed though, and can be observed in the reservoir simulation hydrographs in Appendix C.4. The simulated releases at Friant Dam for this alternative were maintained with the occurrence of an annual 4-percent chance exceedence storm runoff centering at Friant Dam, and an annual 1-percent chance exceedence event centered at New Exchequer and Don Pedro dams(Figures C.4-6b, C.4-6g, and C.4-6k). By comparison, objective flows modeled at baseline conditions were maintained at Friant Dam with a simulated annual 10-percent chance exceedence event, and at New Exchequer and Don Pedro by an annual 4-percent chance exceedence event (Figures C.1-8b, C.1-11c, and C.1-12c), in effect increasing the simulated level of flood protection provided by each flood damage reduction facility. Friant Dam outflows, representative of a simulated 4-percent chance exceedence event generated by SJQ-B02A, result in a reduction in peak maxima (from baseline) of 11 percent. Likewise, peak maxima at New Exchequer and Don Pedro (with runoff centerings directed at them) resulted in a 73- and 72-percent reduction, respectively.

Calculated peak reduction values at several of the index gage locations, for several synthetic frequency frequencies within the centering groups, are found to be zero. Peak reductions of zero values are appropriate in these instances only because the maximum peak flows for both the baseline and alternative are the same. Their difference is simply zero. Parallels are noticed in the response of both Don Pedro and Modesto gages to the increased available storage capacity and objective flow limits. Negative values, indicative of an increase in peak flows associated with the modeled peak reduction values, are attributed to an increase in allowable objective flows downstream of the Don Pedro facility. With the exception of the Friant storm runoff centering, a reduction of peak maxima occurs at each flood control facility when a synthetic annual 2-percent chance exceedence flood runoff centering is targeted at its basin. Maximum peak reduction benefits at the mainstem index gage locations, however, were at or near the 1-percent chance exceedence event.

### Alternative Scenario SJQ-B03A

The results of scenario SJQ-B03A are presented in Attachment C.4, Tables C.4-7a and C.4-7b. Examination of this alternative proves to be conceptually different from others presented herein. Because comparison of peak discharge and peak volume for this modeled alternative are designed to permit the passage of greater volumes, a direct comparison of baseline data to alternative data is inadequate. Direct observation of the output data generated by this alternative does, however, reveal that simply increasing downstream objective flow limits allows the flood damage reduction facilities to increase their outflows sooner. The direct result is to allow the flood control facility to pass the inflow volumes associated with the first flood wave volumes as described in *Appendix B – Synthetic Hydrology Documentation*. The indirect result is that the flood control pool is allowed to stay lower longer, allowing the facility to better attenuate the incoming peak flood wave. This alternative of increasing downstream objective flows provided a greater benefit for the more frequent synthetic exceedence frequencies with the increased objective flow criteria, allowing manageable releases to be made sooner.

Reduction in peak discharges are noticeably smaller at mainstem locations downstream of tributary contributions, compared to the reduced peak regulated outflows of the flood control facilities for all seven synthetic exceedence frequencies. This is attributed, in part, to the significantly different conveyance capacities between the mainstem, its tributaries, and the added effect of various local, unregulated inflows. Operations at the Don Pedro flood damage reduction facility, for example, are effected by objective flow criteria at downstream index gage locations. The modified releases at Don Pedro for this alternative are operated to keep flows at or below 15,000 cfs (an increase of 6,000 cfs) just downstream of Dry Creek's confluence to the Tuolumne River. As can be observed in the alternative reservoir simulation hydrographs in Attachment C.4, simulated objective flow criteria at Don Pedro Dam were maintained by all events occurring more frequently than and including an annual 4-percent chance exceedence storm runoff centering focused at Don Pedro Dam (Figures C.4-7a through C.4-7d). Similarly, objective flows modeled at baseline conditions were also maintained at Don Pedro by the occurrence of an annual 4-percent chance exceedence event or greater (Figure C.1-12c).

Volumes attenuated through the modeling of Alternative SJQ-B03 are significant in quantity, clearly exhibiting flood damage reduction benefits for less frequent events, such as the 2-, 1-, 0.5-, and 0.2-percent exceedence intervals. Reductions in peak volume at Don Pedro remain consistent with the occurrence of a 2-percent chance exceedence flood runoff event centered at or downstream of the Newman index gage location, changing to a 1-percent exceedence as the centerings are focused further upstream. Parallels are noticed in the response of both Don Pedro and Modesto index gage locations to the increased objective flow limits. Negative values, indicative of a net increase in peak flow maxima and volume associated with the modeled alternative, are attributed to an increase in the simulated objective flows at the Don Pedro facility. Noticeably, both gages react in unison as would be expected.

As exemplified in Table C.4-7a, simulations of alternative SJQ-B03A indicate no benefit in the projected level of flood protection at Don Pedro Dam. Existing results indicate that releases from Don Pedro Dam provide protection for the occurrence of a 4-percent chance exceedence event in both the baseline and simulation of alternative scenario SJQ-B03A.

**Alternative Scenario SJQ-B04A**

The results of scenario SJQ-B04A are presented in Attachment C.4, Tables C.4-8a and C.4-8b. As in the examination of SJQ-B03A, analysis of this alternative proves different conceptually than others presented herein. Because the design of this alternative permits the passage of greater volumes through increases to objective release criteria on the upper reach of the San Joaquin, Merced, and Tuolumne rivers, a direct comparison of baseline data to alternative data is inadequate. Direct observation of the output data generated by this alternative does however, expose that simply increasing downstream objective flow limits allows the flood damage reduction facilities to increase their outflows sooner. The direct result is that the flood control facility is allowed to pass the inflow volumes associated with the first three flood wave volumes as described in *Appendix B – Synthetic Hydrology Documentation*. The indirect result is that the flood control pool is allowed to stay lower longer, in some instances allowing the facility to better attenuate the incoming peak flood wave. This alternative of increasing downstream objective flows provided a greater benefit for the more frequently occurring exceedence events.

Reduction in peak discharge maxima are noticeably smaller at mainstem locations, downstream of tributary contributions, in comparison to the reduced peak regulated outflows of the flood control facilities for all seven synthetic exceedence frequencies being simulated. This is attributed, in part, to the largely different conveyance capacities between the mainstem, its tributaries and the added cumulative effect of various local inflows. Operations at each of the flood damage reduction facilities are effected by objective flow criteria at downstream index gage locations. The modified releases at Friant Dam for this alternative are operated to keep flows at or below 12,000 cfs (up from a baseline of 8,000 cfs) just downstream of Little Dry Creek's confluence with the San Joaquin River. At New Exchequer Dam, objective flow criteria have been increased to maintain flows at or below 7,000 cfs (up from a baseline of 6,000 cfs) in the Merced River at Stevinson and at Don Pedro Dam, 15,000 cfs (up from a baseline of 9,000 cfs) within the Tuolumne River below its confluence with Dry Creek.

As can be observed in the resultant simulation hydrographs presented for this alternative in Attachment C.4, increased flood protection benefits are achieved at Friant Dam for simulated runoff centerings targeted at Friant, New Exchequer, and Don Pedro flood damage reduction facilities. The ability for Friant Dam to maintain operational downstream release criteria at or below required limits changes from a 10-percent to a 4-percent, from a 4-percent to a 1-percent, and from a 2-percent to a 1-percent annual chance exceedence, for targeted centerings at Friant, New Exchequer, and Don Pedro, respectively (Table C.4-8a). With the exception of a change in the ability of New Exchequer Dam to provide an increase in flood protection from that of a 2-percent to a 1-percent chance annual exceedence event at New Exchequer Dam, as a runoff centering was targeted at it; no other benefits are observed with in simulations of this alternative.

Volumes attenuated by the Friant Dam facility, through the modeling of Alternative SJQ-B04A are significant in capacity and clearly exhibit flood damage reduction benefits. Parallels are noticed in the response of both Don Pedro and Modesto gages to the increased objective flow limits. Negative values, indicative of a net increase in peak flow maxima associated with the modeled alternative, are attributed to an increase in objective release criteria at the Don Pedro facility. Noticeably, both gages react in unison as would be expected.

**Alternative Scenario SJQ-B05A**

The results of scenario SJQ-B05A are presented in Attachment C.4, Tables C.4-9a and C.4-9b. During every flood runoff centering, with the exception of the one centered at Newman, the largest percent reduction in peak flow maxima occurred at Don Pedro Dam during the 2-, 1-, and 0.2-percent chance exceedence events. This is due mostly to the large increase in available flood space in this facility imposed by this alternative. Reduction in peak discharges are noticeably smaller at mainstem locations, compared to the reduced peak regulated outflows of the flood control facilities themselves. This is attributed to the different conveyance capacities between the mainstem and its tributaries, and the immediate local effects of increasing available flood storage at the reservoirs on each tributary (Friant, New Exchequer, and Don Pedro). Operations of Friant, New Exchequer, and Don Pedro dams are affected by objective flow criteria at downstream index gage locations. Friant Dam releases are operated to keep flows at or below 8,000 cfs downstream of its confluence with Little Dry Creek and a maximum of 6,500 cfs at a control point below Mendota Dam. Operational releases at New Exchequer Dam are to be maintained at or below 6,000 cfs and at Don Pedro Dam, at or below 9,000 cfs just downstream of the Dry Creek confluence with the Tuolumne River. As can be observed in the alternative reservoir simulation hydrographs in Attachment C.4, objective flows simulated by this alternative were maintained at Friant Dam with an annual 4-percent chance exceedence event centered at Friant; at New Exchequer Dam with an annual 2-percent chance exceedence event centered at New Exchequer; and at Don Pedro Dam with an annual 2-percent chance exceedence event centered at Don Pedro (Figures C.4-9a, C.4-9f, and C.4-9j). By comparison, objective flows modeled at baseline conditions were maintained at Friant with the occurrence of an annual 10-percent chance exceedence event, and at New Exchequer and Don Pedro with an annual 4-percent chance exceedence event centered over those facilities (Figures C.1-8b, C.1-11c, and C.1-12c).

**Alternative Scenario SJQ-B06A**

The results of scenario SJQ-B06A are presented in Attachment C.4, Tables C.4-10a and C.4-10b. As previously explained, comparison of peak discharge maxima and peak volume, for this modeled alternative, are designed to permit the passage of greater volumes. A direct comparison of baseline data to alternative data is inadequate. Direct observation of the output data generated by this alternative does, however, expose that simply increasing downstream objective flow limits allows the flood damage reduction facilities to increase their outflows sooner. The direct result is allowing the flood control facility to pass the inflow volumes associated with the first flood wave volumes as described in *Appendix B – Synthetic Hydrology Documentation*. The indirect result is that the flood control pool is allowed to stay lower, longer, allowing the facility to better attenuate the incoming peak flood wave. This alternative of increasing downstream objective flows typically provides a greater benefit for more frequent exceedence frequencies, with the increased objective flow criteria allowing manageable releases to be made sooner.

Reductions in peak discharges are noticeably smaller at mainstem locations, downstream of tributary contributions, compared to the reduced peak regulated outflows at Friant Dam for all seven synthetic exceedence frequencies. This is attributed, in part, to the largely different conveyance capacities between the mainstem, its tributaries, and the added effect of various unregulated local inflows. Operations at the Friant flood damage reduction facility are effected by objective flow criteria at a downstream index gage location. The modified releases at Friant

Dam for this alternative are operated to keep flows at or below 16,000 cfs (up from an existing baseline of 8,000 cfs) just downstream of Little Dry Creek's confluence with the San Joaquin River. As can be observed in the alternative's reservoir simulation hydrographs representative of Friant Dam, simulated objective flows were maintained by all events including and occurring more frequently than an annual 4-percent chance exceedence storm runoff centered at Friant Dam (Figures C.4-10a through C.4-10d). By comparison, the objective flows representing simulated baseline conditions were exceeded at Friant Dam by events more frequent than and including a 10-percent chance exceedence event (Figure C.1-8b). Volumes attenuated through the modeling of Alternative SJQ-B06 are significant in capacity and clearly exhibit flood damage reduction benefits. Reductions in peak maxima and volume remains consistent with the occurrence of 1- and 0.5-percent chance exceedence events for flood centerings at or immediately downstream (El Nido) of the Friant Dam index gage location. Negative values, indicative of a net increase in peak flow maxima and volume associated with the modeled alternative, are attributed to an increase in the simulated objective flows at the Don Pedro facility.

As exemplified in Table C.4-10a, the simulation of alternative SJQ-B06A provides an immediate beneficial increase in the projects ability to manage simulated floods of greater magnitude. The existing baseline results indicate that though the peak maxima increase in the simulation of the 50-, 10-, and 4-percent chance exceedence events, increasing the operational objective flow value allows Friant Dam to increase its ability to maintain downstream objective flow criteria from that of a 10-percent chance exceedence event during baseline simulations to that which occurs during the simulation of an annual 4-percent chance exceedence event. Allowing Friant Dam to increase its downstream objective flow yields a net reduction in the peak maxima of the simulated 2-percent chance exceedence event of 24.5 percent.

### Alternative Scenario SJQ-B07A

The results of scenario SJQ-B07A are presented in Tables C.4-11a and C.4-11b. Because comparison of peak discharge maxima and peak volume, for this modeled alternative, are designed to permit the passage of greater volumes, a direct comparison of baseline data to the alternative data is inadequate. Direct observation of the output data generated by this alternative does however, expose that simply increasing downstream objective flow limits allows the flood damage reduction facilities to increase their outflows sooner. The direct result is allowing the flood control facility to pass the inflow volumes associated with the first flood wave volumes as described in *Appendix B – Synthetic Hydrology Documentation*. The indirect result is that the flood control pool is allowed to stay lower, longer, allowing the facility to better attenuate the incoming peak flood wave. This alternative of increasing downstream objective flows typically provides a greater benefit for events of a more frequent exceedence probability, with the increased objective flow criteria allowing manageable releases to be made sooner.

Reductions in peak discharges are noticeably smaller at mainstem locations, downstream of tributary contributions, in comparison to the reduced peak regulated outflows of New Exchequer Dam for all seven synthetic exceedence frequencies being simulated. This is attributed, in part, to the significantly different conveyance capacities between the mainstem and its tributaries and the added effect of various unregulated local inflows. Operations at the New Exchequer flood damage reduction facility are effected by objective flow criteria at a downstream index gage location. The modified releases at New Exchequer for this alternative are operated to keep flows at or below 8,000 cfs (an increase of 2,000 cfs) in the Merced River at Stevinson. As can be observed in the alternative reservoir simulated hydrographs in Attachment C.4, the simulated objective flows were maintained by all simulated events more frequent than, and including the simulated annual 2-percent chance exceedence storm runoff centering, focused at New Exchequer Dam (Figures C.4-11a through C.4-11d). By comparison, objective flows simulating baseline conditions were exceeded at New Exchequer (with a centering at New Exchequer) by events occurring in greater frequency than the simulated 4-percent chance exceedence event (Figures C.1-11c through C.1-11g). Volumes attenuated through the modeling of Alternative SJQ-B07 are significant in quantity and clearly exhibit flood damage reduction benefits. Negative values, indicative of a net increase in peak flow maxima and volume associated with the modeled alternative, are attributed to an increase in the simulated objective flows at the Don Pedro facility.

As exemplified in Table C.4-11a, simulations of alternative SJQ-B07A provide an immediate beneficial increase in the projected level of flood protection at New Exchequer Dam. Existing baseline results indicate that simulated releases from New Exchequer Dam provide roughly a 4-percent chance exceedence level of protection while the simulated alternative provides just over an annual 2-percent chance exceedence level of protection, resulting in a reduction of the peak maxima by 63.8 percent.

## MAINSTEM FLOOD REDUCTION ALTERNATIVES INCORPORATING FLOODPLAIN STORAGE BASINS AND RESERVOIR REOPERATIONS

### Introduction

An approache to solving the problem of not having adequate water control alternatives in flood management operations is to find areas to which peak flood volumes can be temporarily diverted and detained. Taking advantage of one of the basic benefits of using simulation models, modifications were made to the original baseline HEC-5 flood control simulation model to do just that. Off-stream storage areas were coded into a copy of the simulation model input file. This alteration allowed for a "modified baseline" to be established, representing how the existing flood management system would function with additional flood storage areas. The result is a set of "with-additional-storage" hydrographs to use in comparison with the "without-additional-storage" (baseline) hydrology. Comparison of the "modified baseline" and the "original baseline" hydrology allow planners and managers to make quantitative assessments of the effect an off-stream storage site has on attenuating in-stream peaks and flow volumes. Additionally, this modified baseline model allowed for further changes and combinations of changes to the model's representation of individual reservoir's flood operating criteria, such as increasing its available flood conservation space.

### Selection of Floodplain Storage Areas

In order to evaluate the potential effectiveness of floodplain storage in terms of reducing peak flows, several representative storage areas were evaluated using the HEC-5 model. Five locations along the San Joaquin River were identified as having hydraulic characteristics suited for diverting and temporarily storing flood runoff (Table VI-5). The representative floodplain

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storage areas that were chosen for evaluation were determined by using the following considerations:

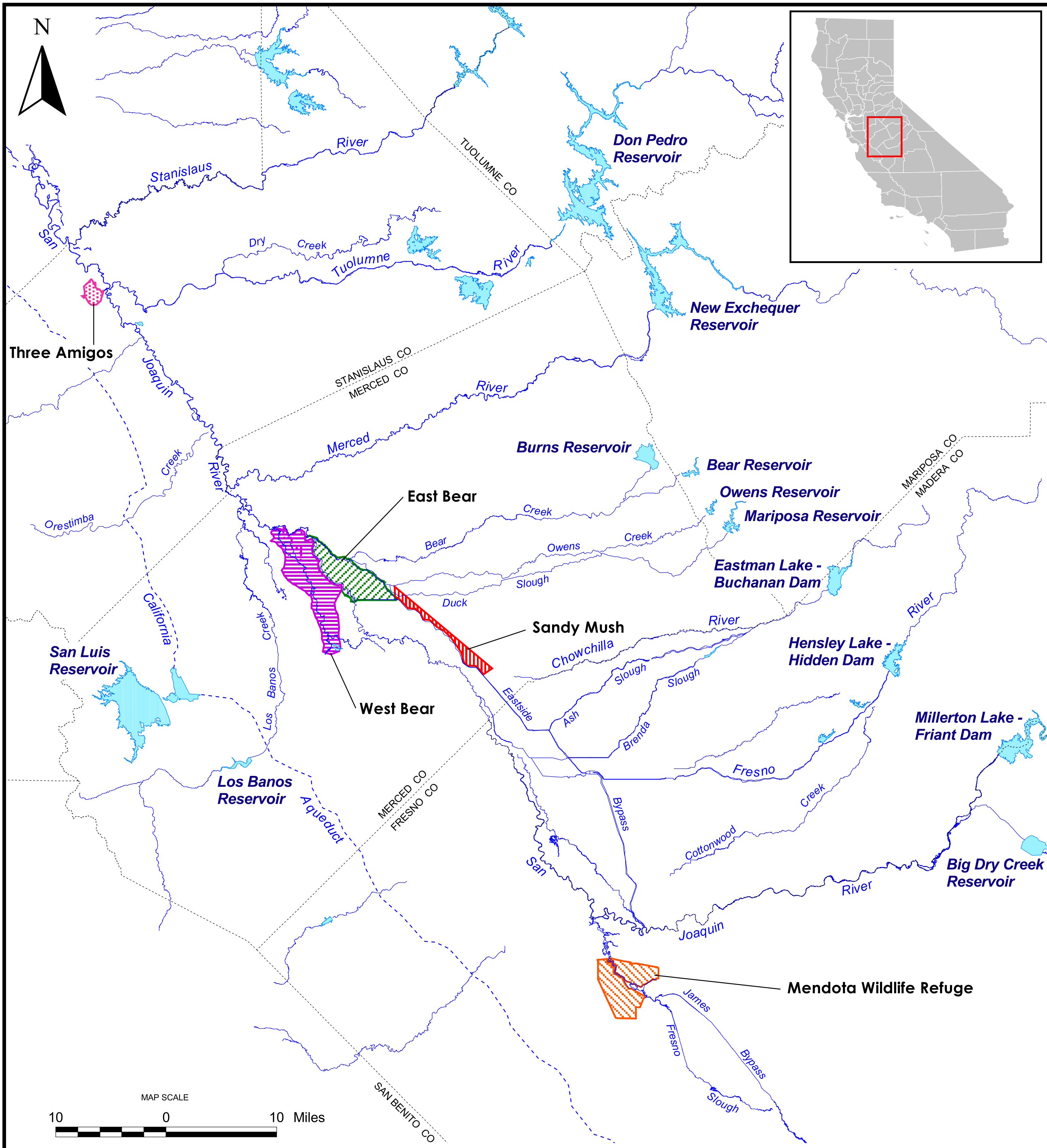
- Public lands currently in or planned for wetland restoration.
- Areas that have flooded in the past, as recorded in the Sacramento and San Joaquin River Basins, Post-Flood Assessment (March 1999), which included the flood events of 1983, 1986, 1995, and 1997.
- Inundation maps prepared for the Comprehensive Study, placing special emphasis on areas that flooded more frequently.
- Topographic suitability (ability to contain and drain flows using existing terrain).

The baseline HEC-5 San Joaquin lower basin reservoir operations model was then modified to include these five storage areas. Figure VI-3 exhibits the proposed location and extent of each storage basin as they were modeled along the San Joaquin River. The physical constraints of each storage area, such as their rate of inflow and maximum storage capacities, were based on the topographical characteristics of each area of inundation and their average flood depth determined through parallel hydraulic modeling efforts (*Technical Appendix D – Hydraulic Technical Documentation*).

**TABLE VI-5**

**FLOODPLAIN STORAGE AREAS**

| Floodplain Storage | Diversion Location | Maximum Storage Capacity (acre-feet) |
|---|---|---|
| Mendota Wildlife Area | Along Fresno Slough upstream of Mendota | 21,676 |
| Sandy Mush | Eastside/Mariposa Bypass upstream of El Nido | 20,500 |
| West Bear | San Joaquin River upstream of Bear River confluence | 35,600 |
| East Bear (Bravel Slough) | Eastside Bypass upstream of Owens Creek confluence | 35,000 |
| Three Amigos | San Joaquin River immediately downstream of Tuolumne River confluence | 14,650 |




## MAP LEGEND

Transitory Storage Basins
Lake or Reservoir
River or Stream
County Boundary

SACRAMENTO & SAN JOAQUIN RIVER BASINS
COMPREHENSIVE STUDY

# TRANSITORY STORAGE BASIN LOCATIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

**Reservoir Selection and Reoperation**

Three flood damage reduction reservoirs, each tributary to the San Joaquin River, were chosen for these alternatives analysis based on their current levels of flood protection. It was anticipated that flood damage reduction benefits would be attained by allocating additional flood storage at these facilities. Those chosen were Friant Dam, New Exchequer Dam, and Don Pedro Dam, each of which barely provide protection against the occurrence of a storm equivalent to that of a 2-percent chance exceedence event. This alternatives analysis set forth to analyze the effects of adding various storage combinations of additional flood control space in these reservoirs and the influence those additional volumes have on the diverted flood volumes and the peak flow and volumes within the mainstem of the San Joaquin River. Table VI-6 presents the myriad of possible combinations and permutations of additional flood control space modeled in this analysis, as well as the total flood control space incorporated into San Joaquin drainage basin. These volumes were chosen based on: 1) the practicality of attaining additional flood control space within each reservoir; 2) preliminary benefits analysis of previous investigations (Grid Analysis); and 3) existing system constraints. At Friant Dam, flood control storage increases of 100 and 170 TAF were analyzed, at New Exchequer 50 and 100 TAF, and at Don Pedro 100 and 200 TAF.

**HEC-5 Modeling Approach**

The floodplain storage areas were treated as storage basins or reservoirs and modeled with the baseline HEC-5 model such that excess flows from the San Joaquin River were diverted directly into the storage basins. Diversions were coded within the model input file to begin when flows in the mainstem of the San Joaquin River were near the maximum channel capacity at that location. The rate at which diverted flows enter each floodplain storage area were defined through parallel modeling efforts of the San Joaquin UNET model developed for the Comprehensive Study (Appendix D). Output from the simulated annual 0.2-percent chance exceedence event was used to generate best-fit curves of total in-stream flow versus diverted flow for each floodplain storage area. The annual 0.2-percent chance exceedence event was chosen as a conservative estimator ensuring that the maximum conveyance capacity and diversion rates are represented. Total and diverted flow values entered into the HEC-5 model were selected from these curves.

## TABLE VI-6

## FLOOD CONTROL STORAGE INCREASES

| Alternative Scenario | Flood Control Storage Combinations (TAF) | | | |
|---|---|---|---|---|
| | Friant | New Exchequer | Don Pedro | Total |
| Modified Baseline | 0 | 0 | 0 | 0 |
| *SJQ-T01A | 100 | 0 | 0 | 100 |
| *SJQ-T02A | 170 | 0 | 0 | 170 |
| SJQ-T03A | 0 | 50 | 0 | 50 |
| *SJQ-T04A | 100 | 50 | 0 | 150 |
| *SJQ-T05A | 170 | 50 | 0 | 220 |
| SJQ-T06A | 0 | 100 | 0 | 100 |
| *SJQ-T07A | 100 | 100 | 0 | 200 |
| *SJQ-T08A | 170 | 100 | 0 | 270 |
| SJQ-T09A | 0 | 0 | 100 | 100 |
| *SJQ-T10A | 100 | 0 | 100 | 200 |
| *SJQ-T11A | 170 | 0 | 100 | 270 |
| SJQ-T12A | 0 | 50 | 100 | 150 |
| *SJQ-T13A | 100 | 50 | 100 | 250 |
| *SJQ-T14A | 170 | 50 | 100 | 320 |
| SJQ-T15A | 0 | 100 | 100 | 200 |
| *SJQ-T16A | 100 | 100 | 100 | 300 |
| *SJQ-T17A | 170 | 100 | 100 | 370 |
| SJQ-T18A | 0 | 0 | 200 | 200 |
| *SJQ-T19A | 100 | 0 | 200 | 300 |
| *SJQ-T20A | 170 | 0 | 200 | 370 |
| SJQ-T21A | 0 | 50 | 200 | 250 |
| *SJQ-T22A | 100 | 50 | 200 | 350 |
| *SJQ-T23A | 170 | 50 | 200 | 420 |
| SJQ-T24A | 0 | 100 | 200 | 300 |
| *SJQ-T25A | 100 | 100 | 200 | 400 |
| *SJQ-T26A | 170 | 100 | 200 | 470 |
| * *Alternative scenarios presented in Figure VI-18*. | | | | |

Figures VI-4 through VI-7 depict the timing of inflow into each basin as the model passes the synthetic 4-, 2-, and 1-percent chance exceedence events through the system. Once these storage areas reach their maximum capacities, excess flows are redirected back into the main channel. This was accomplished by modeling the floodplain storage areas as "dummy" reservoirs that "fill and spill." Outflow from each dummy reservoir is held at zero while maintaining channel capacity within the mainstem of the San Joaquin River, until its storage capacity is exceeded. At this point: outflows equal inflows, returning outflows in excess of each floodplain storage basin's retaining capacity back into the main channel immediately downstream of the diversion point with a zero routing time. In essence, Figures VI-4 through VI-7 exhibit the total flows diverted through each floodplain storage basin. Figures VI-8 through VI-11 however, reveal the functionality of each basin as each of the seven synthetic exceedence frequency events is processed through the model. Noticeably, in Figures VI-8 through VI-11, the West Bear storage floodplain area is the first of the five basins to begin receiving inflows and fills to its maximum capacity with any event occurring more frequently than an annual 50-percent chance exceedence event. The intent of each diversion is to provide a mechanism for lowering peak stage and

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volume within the mainstem of the San Joaquin River. Figures VI-12 through VI-17 exhibit regulated, in-stream hydrographs representative of the original baseline (without-project) and modified baseline (with-project) flow conditions on the mainstem of the San Joaquin River.

A total of 27 different scenarios of flood control storage combinations between the three selected reservoirs were examined (Table VI-6). The total amount of increased flood control space ranged from 0 to 470 TAF, and was written into the HEC-5 model by decreasing each reservoir's respective conservation volume; thereby effectively lowering its top of conservation elevation. Increasing a reservoir's available flood control space through lowering their individual top of conservation elevations provided a simple mechanistic approach in the application of these alternatives without having to arduously re-design the input structure with respect to the physical and operational characteristics of each reservoir and recalibrate each reservoir.

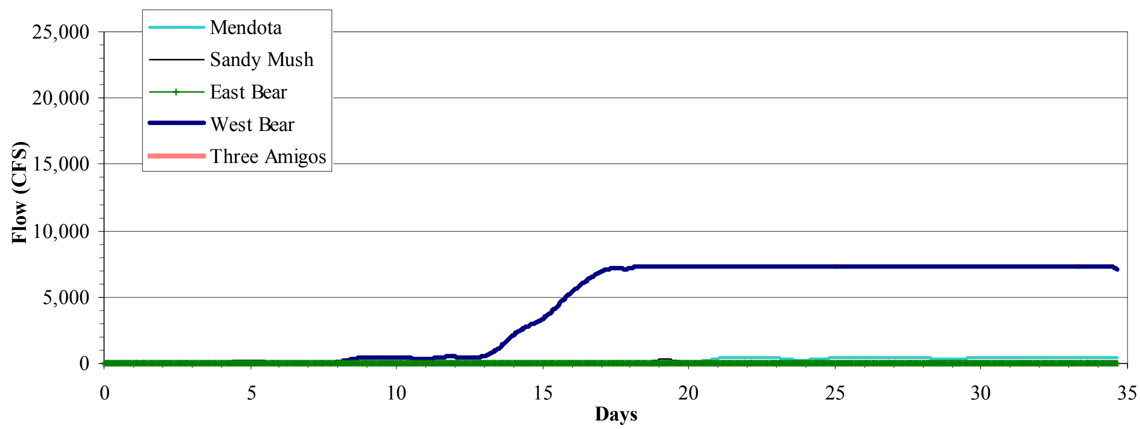
The modified baseline (AAB) and alternative scenario (SJQ-T01A through SJQ-T26A) models were each analyzed with four previously developed centerings (*Appendix B Synthetic Hydrology Technical Documentation*): three of them mainstem storm centerings (El Nido, Newman, and Vernalis) and one tributary centering (San Joaquin River at Friant). These mainstem centerings were selected because of their ability to impact the entire basin, that being the mainstem of the San Joaquin River and its tributaries. Unlike mainstem centerings, the tributary centerings stress individual tributary systems but are not widespread enough to generate the large runoff volumes typical of a basin wide storm. The Friant storm centering was chosen to simulate flood events along the upper San Joaquin River downstream of which the majority of the floodplain storage areas are located.

The effectiveness that increased flood control storage has on reducing floodplain storage volume was analyzed for the occurrence of 4-, 2-, and 1-percent chance exceedence events (Figure VI-18). The influence that increased reservoir flood control space has on floodplain storage volumes is strongly dependent on the location of the floodplain storage area. Increases to flood control storage within Friant, New Exchequer, and Don Pedro have no effect on floodplain storage volumes within the Mendota Wildlife Area, which receives diverted flow from Fresno Slough, upstream of the Friant, New Exchequer, and Don Pedro flood damage reduction facilities.

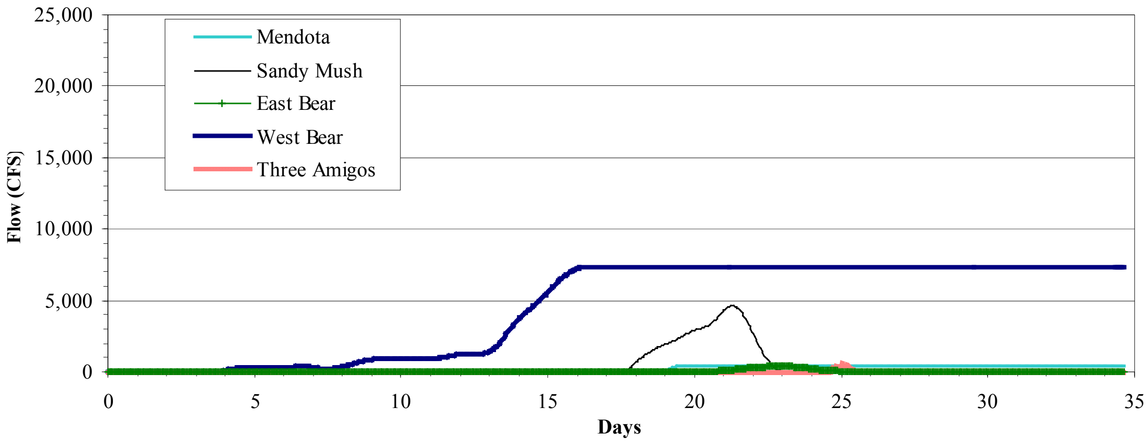
## CONCLUSIONS

These analyses were not designed to recommend specific re-operations, but to serve as valuable references for investigating and communicating the effects of changes in objective releases and available flood storage. It is important to remember that increases in flood storage allocation do not necessarily come at the expense of water supply. Actions like conjunctive use and off-stream storage can bank water for future consumption while freeing space in reservoirs that would be effective in both reducing flood damage and capturing additional water resources seasonally. Likewise, increases in objective flows do not necessarily entail downstream channel alterations. In some cases, existing distribution systems may be used to route floodwater, thereby increasing effective objective releases.

**FIGURE VI-4 FLOW DIVERTED TO FLOODPLAIN STORAGE**
**Friant Centering (4% Chance Exceedence Event)**




**Friant Centering (2% Chance Exceedence Event)**




**Friant Centering (1% Chance Exceedence Event)**

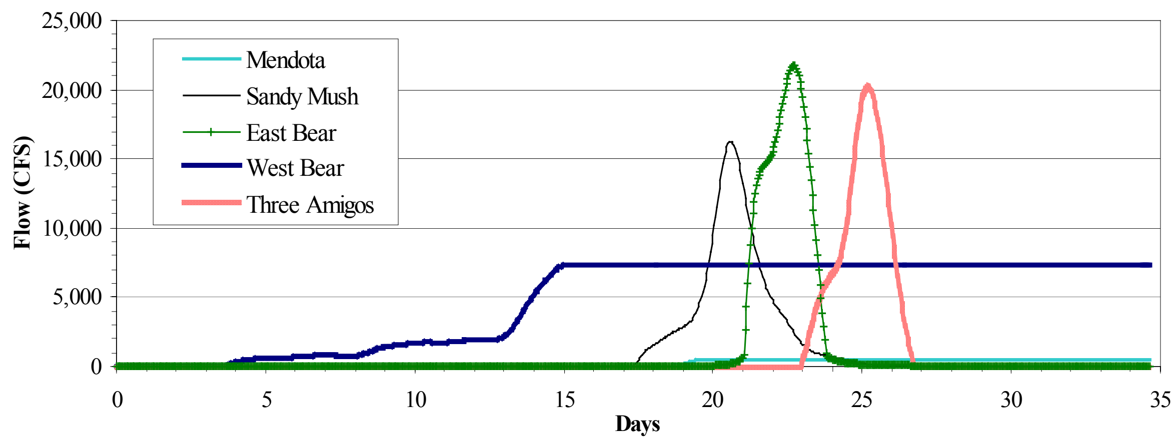



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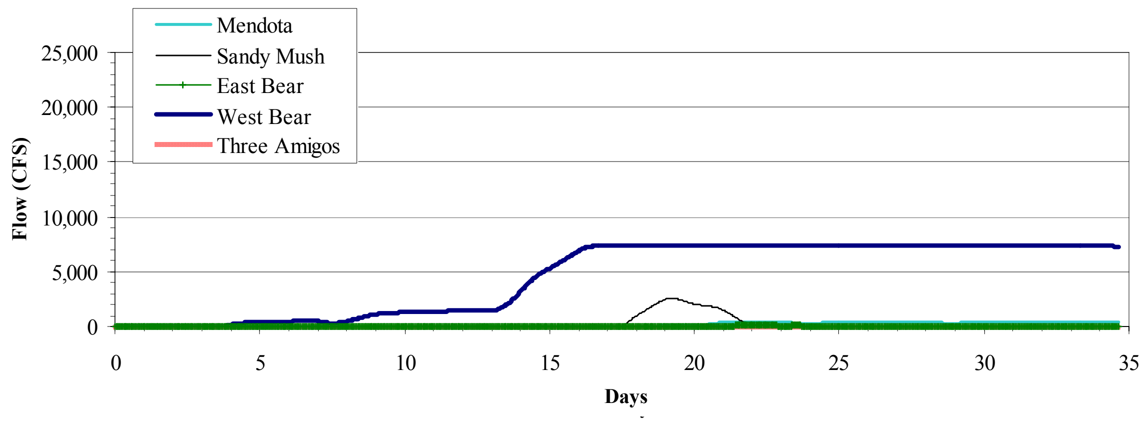
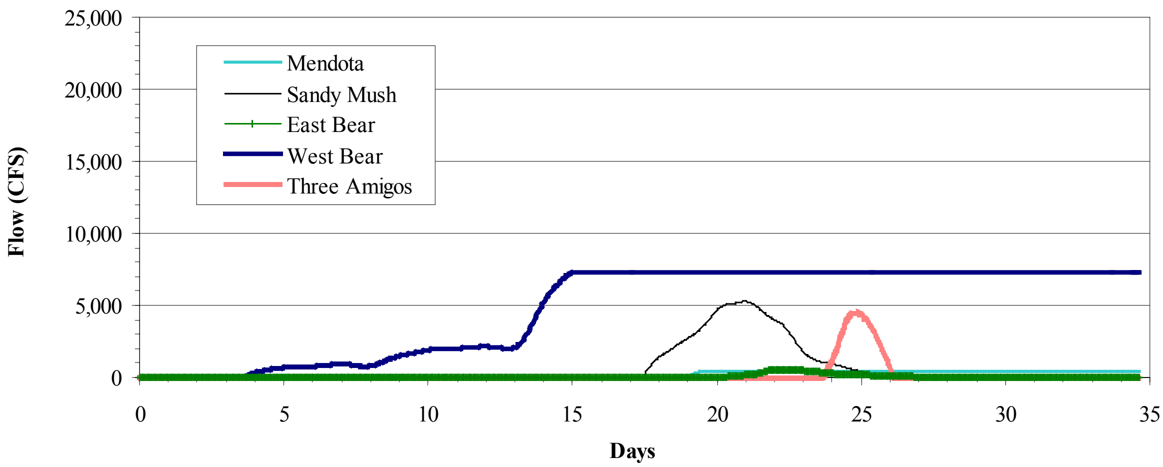
**FIGURE VI-5 FLOW DIVERTED TO FLOODPLAIN STORAGE**

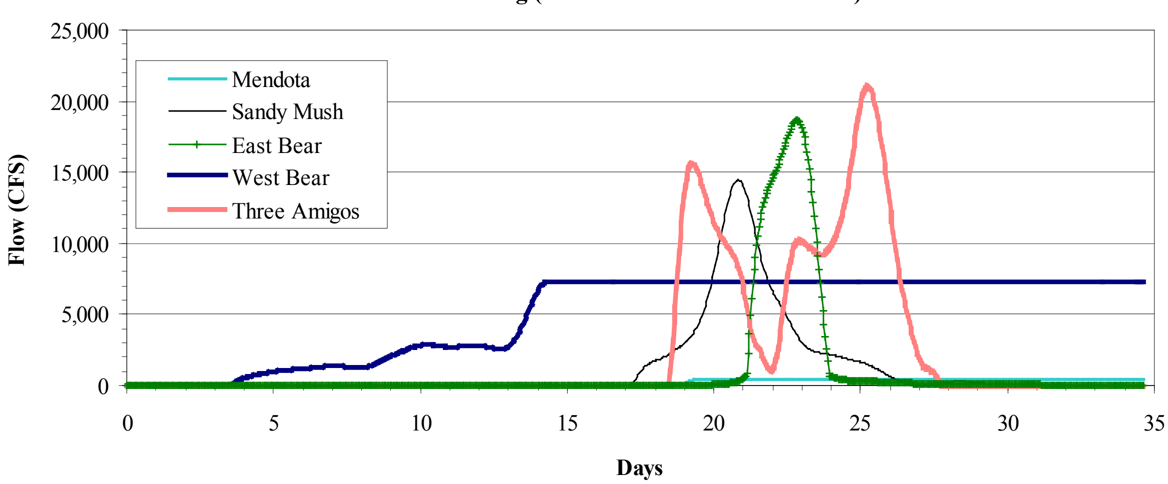
**El Nido Centering (4% Chance Exceedence Event)**




**El Nido Centering (2% Chance Exceedence Event)**



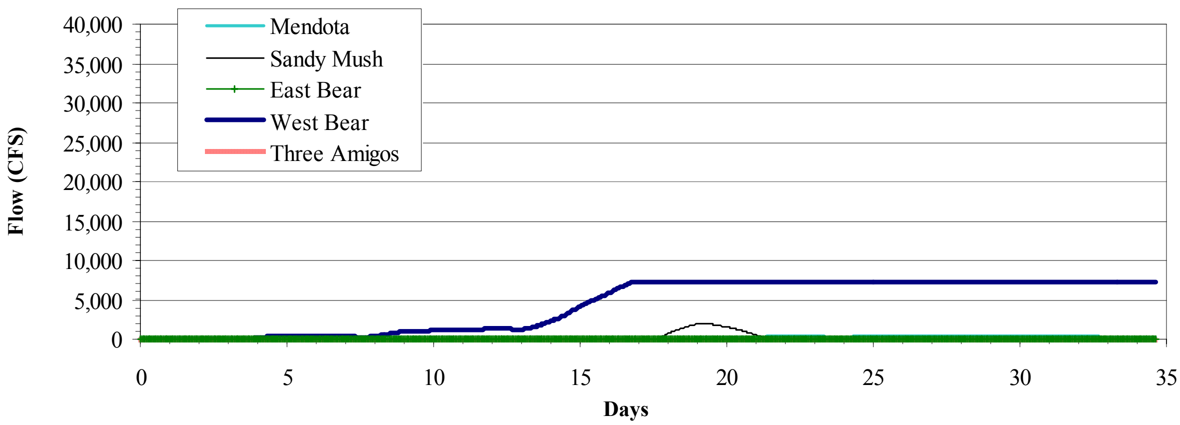

**El Nido Centering (1% Chance Exceedence Event)**



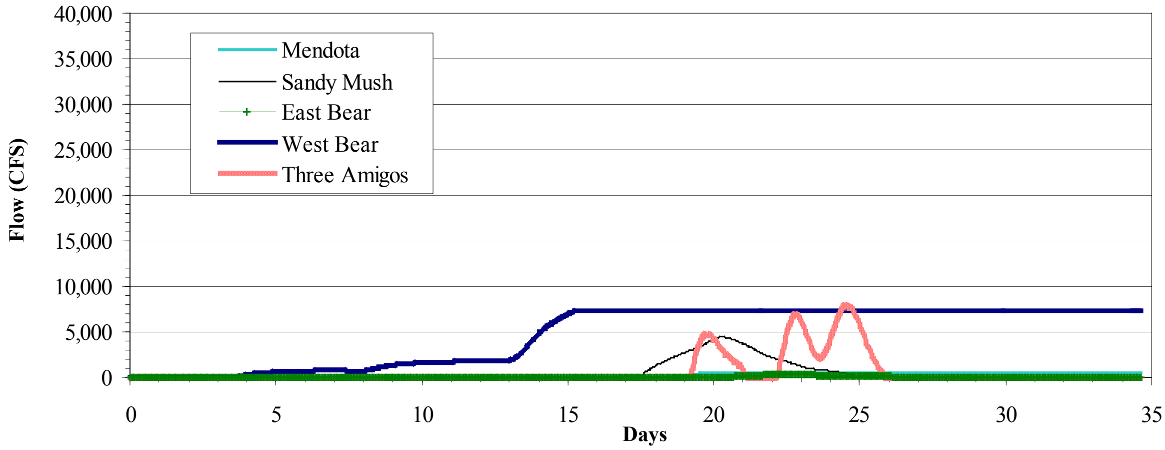

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

**FIGURE VI-6 FLOW DIVERTED TO FLOODPLAIN STORAGE**

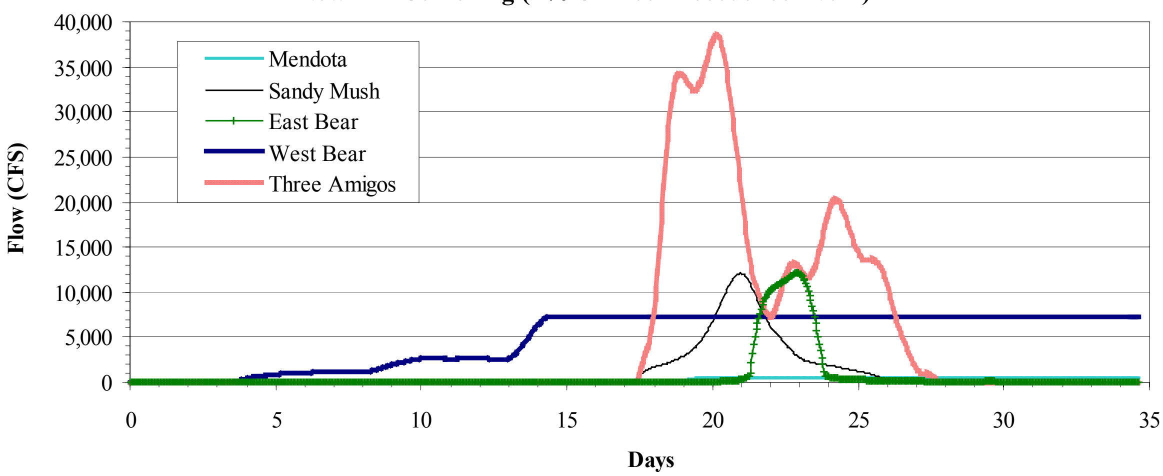
**Newman Centering (4% Chance Exceedence Event)**




**Newman Centering (2% Chance Exceedence Event)**



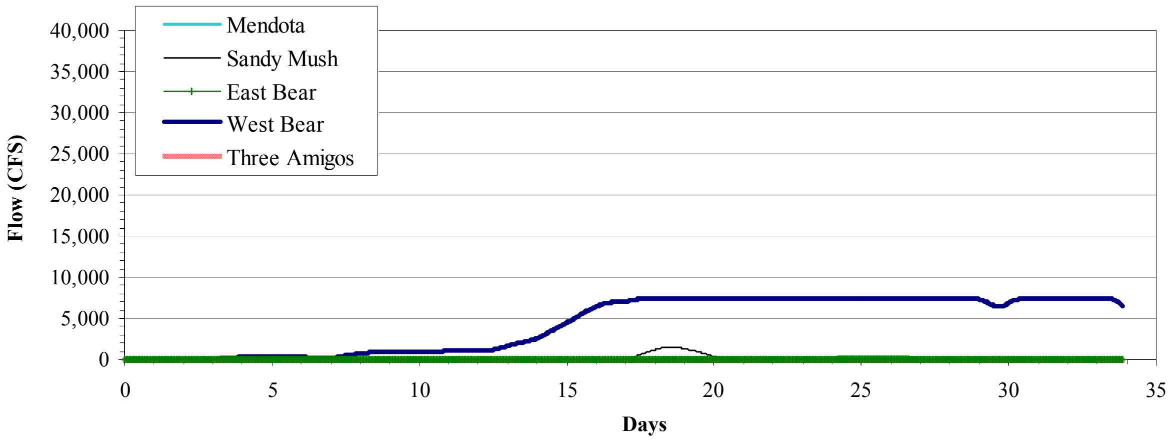

**Newman Centering (1% Chance Exceedence Event)**



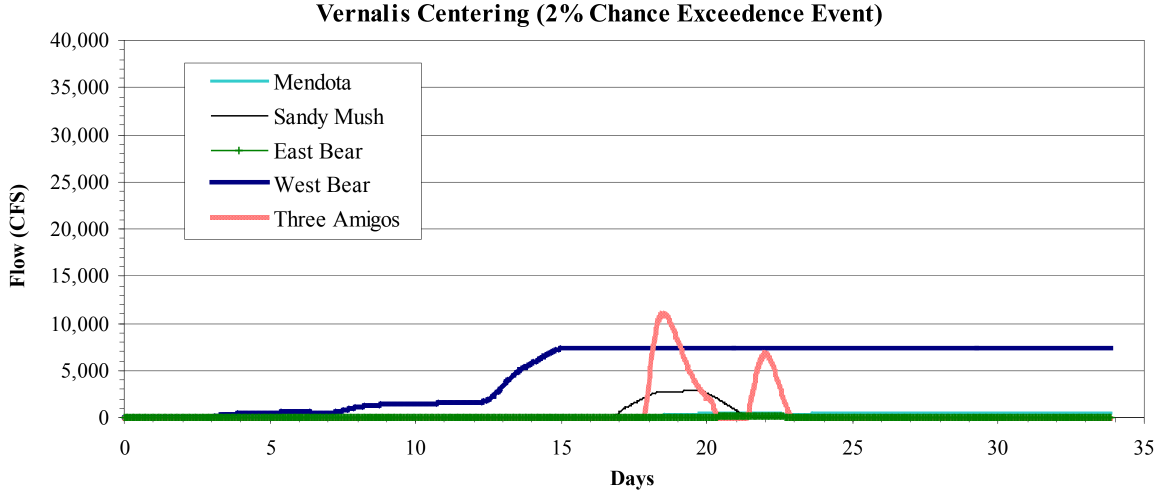

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

**FIGURE VI-7 FLOW DIVERTED TO FLOODPLAIN STORAGE**

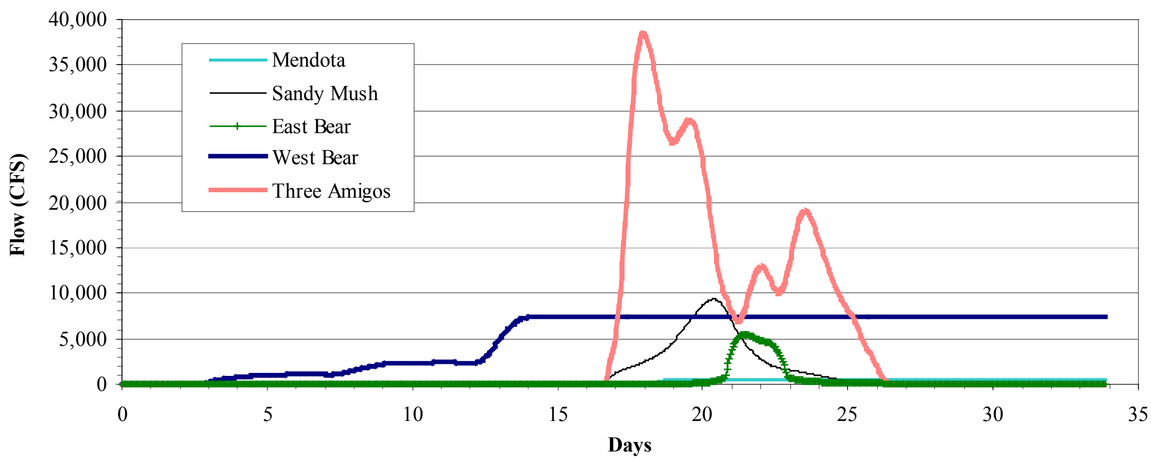
**Vernalis Centering (4% Chance Exceedence Event)**




**Vernalis Centering (2% Chance Exceedence Event)**




**Vernalis Centering (1% Chance Exceedence Event)**




*Note: Prior to use and application, reference the "Expectations of Use" preface.*

**FIGURE VI-8 TOTAL FLOW DIVERTED TO STORAGE - MODIFIED BASELINE, FRIANT CENTERING**

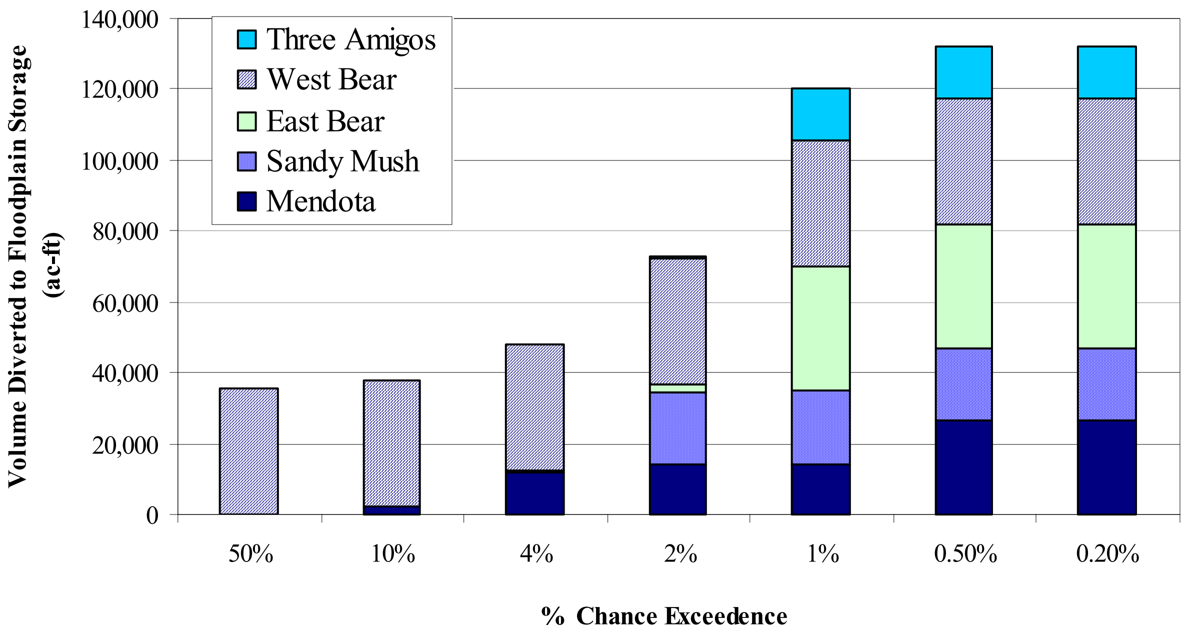
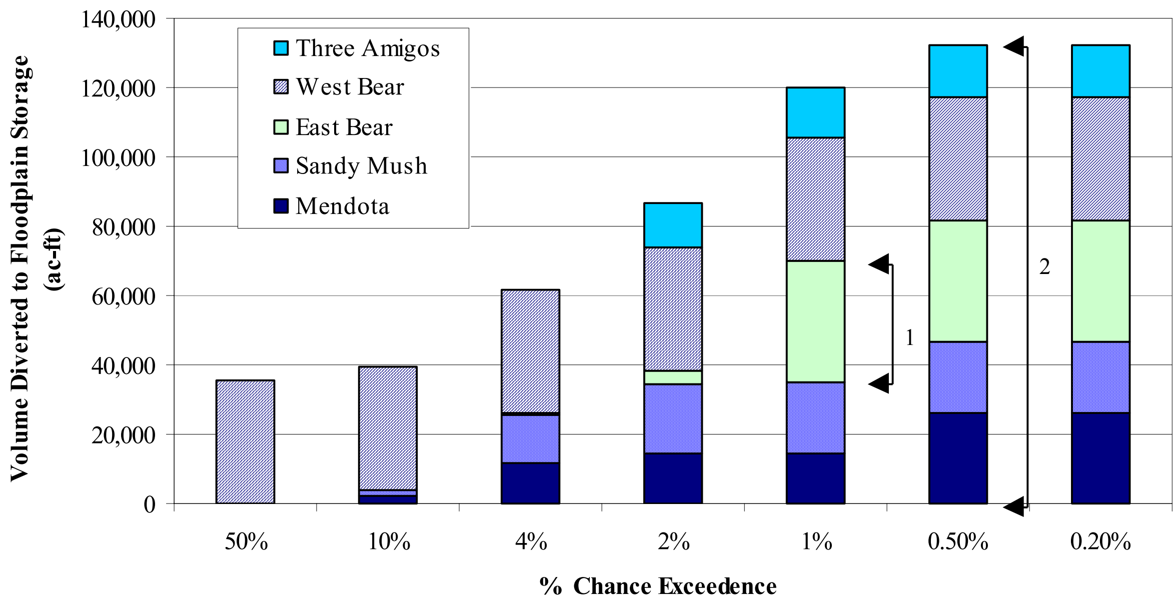



**FIGURE VI-9 TOTAL FLOW DIVERTED TO STORAGE - MODIFIED BASELINE, EL NIDO CENTERING**

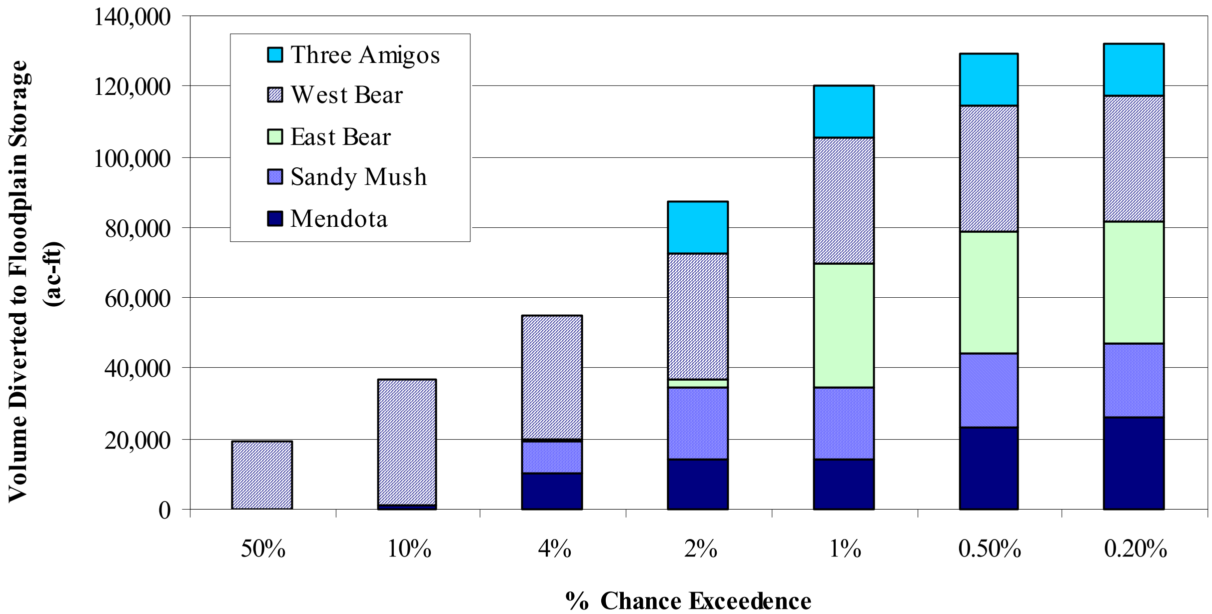



*Notes:*

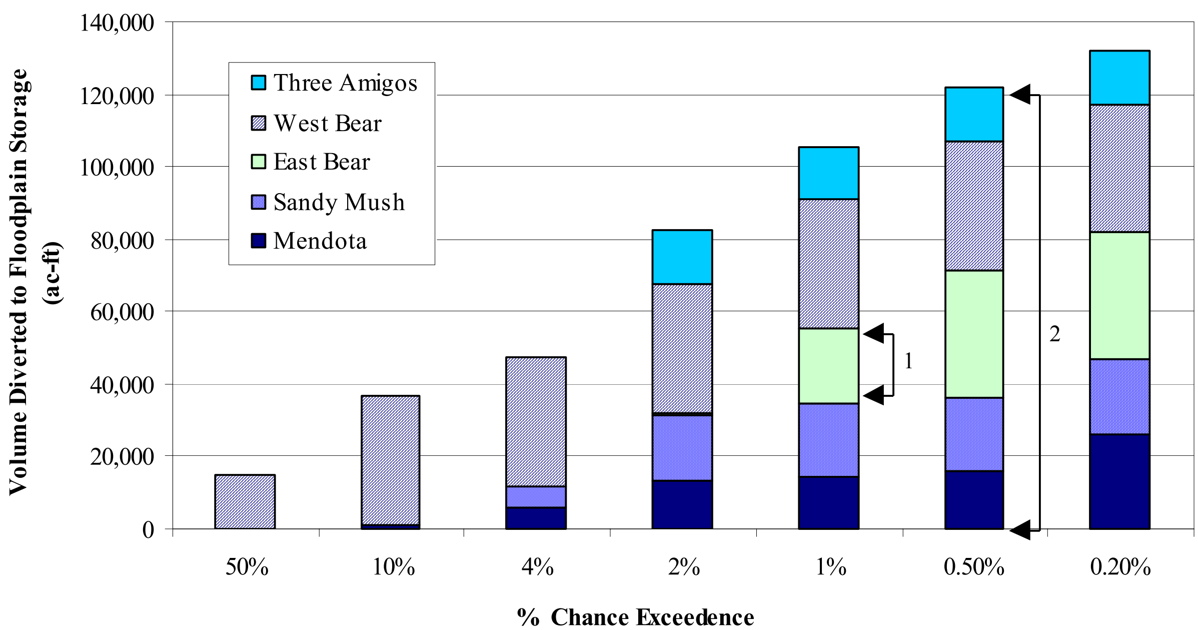
1. *Column lengths, representative of individual floodplain storage basins, represent the total volume captured by that basin, independent of column heights representing the other basins.*
2. *Total column heights represent the average total volume diverted into all floodplain storage basins modeled.*

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

### FIGURE VI-10 TOTAL FLOW DIVERTED TO STORAGE - MODIFIED BASELINE, NEWMAN CENTERING




### FIGURE VI-11 TOTAL FLOW DIVERTED TO STORAGE - MODIFIED BASELINE, VERNALIS CENTERING




*Notes:*
1. *Column lengths, representative of individual floodplain storage basins, represent the total volume captured by that basin, independent of column heights representing the other basins.*
2. *Total column heights represent the average total volume diverted into all floodplain storage basins modeled.*

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

**COMPARISON OF BASELINE AND MODIFIED BASELINE (WITH-FLOODPLAIN STORAGE) FLOW HYDROGRAPHS**

**SAN JOAQUIN RIVER FLOW AT EL NIDO (EL NIDO STORM CENTERING)**

**FIGURE VI-12**

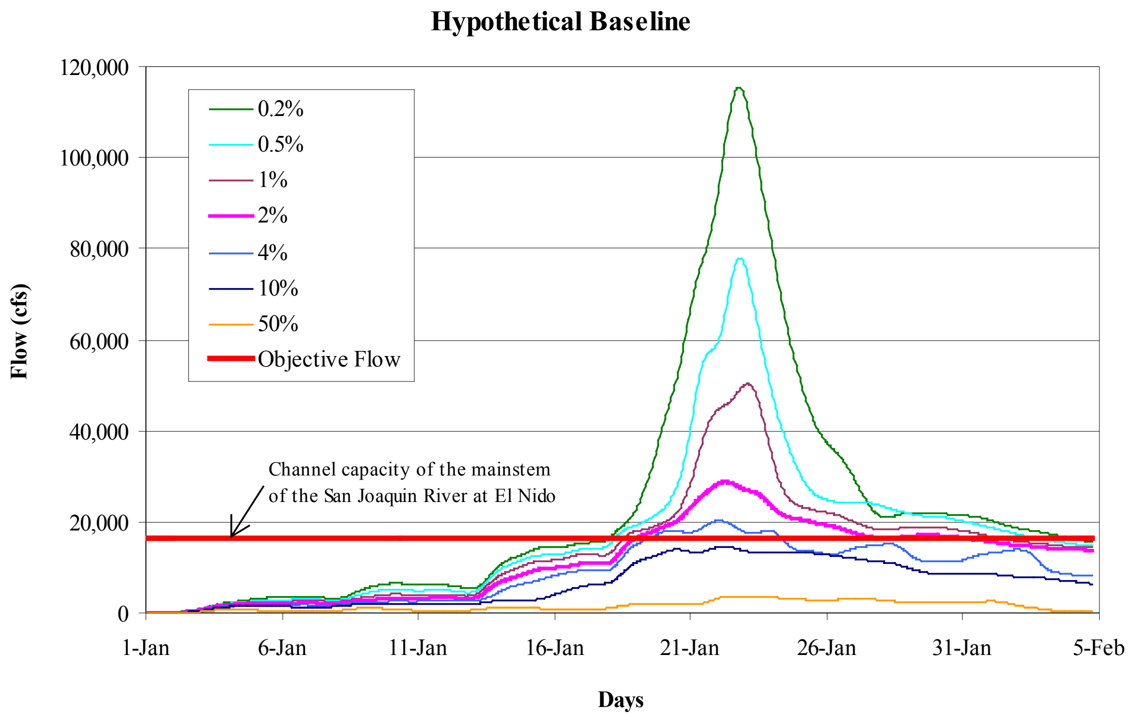
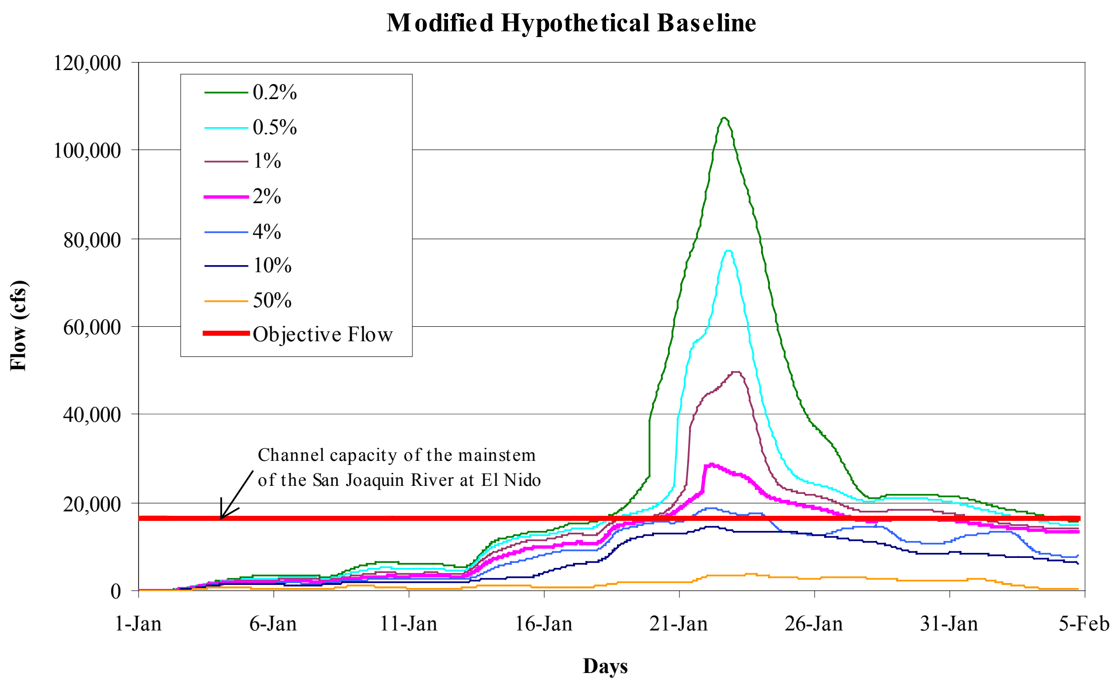



**FIGURE VI-13**

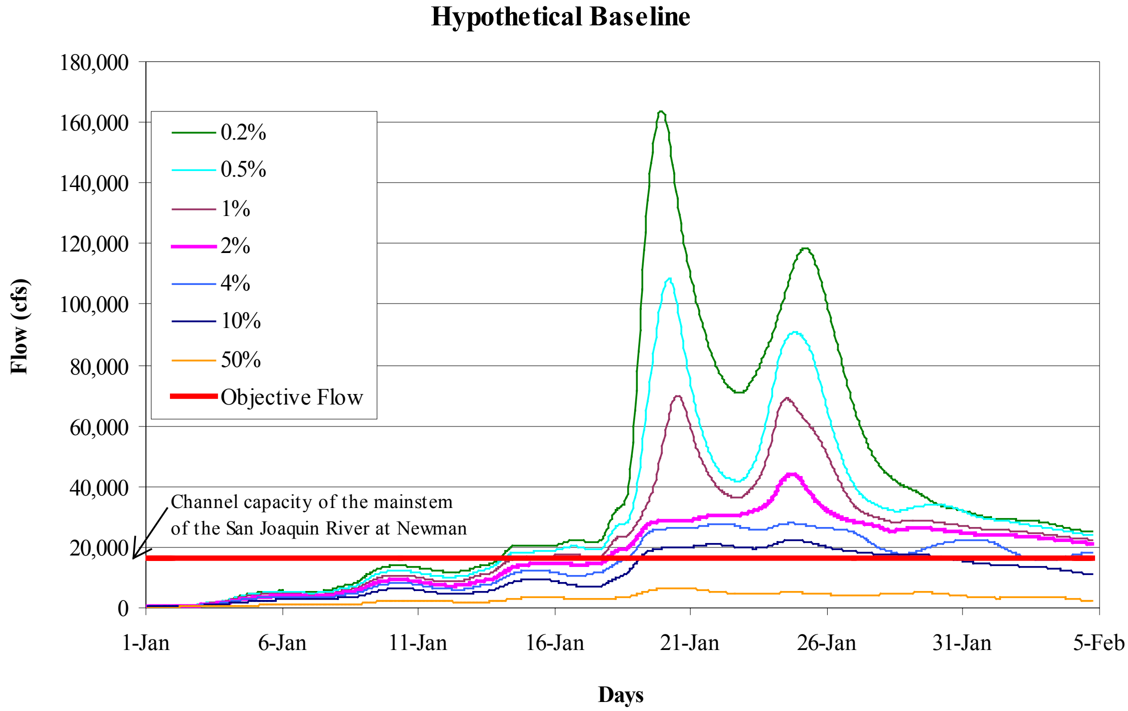



*Note: Prior to use and application, reference the "Expectations of Use" preface.*

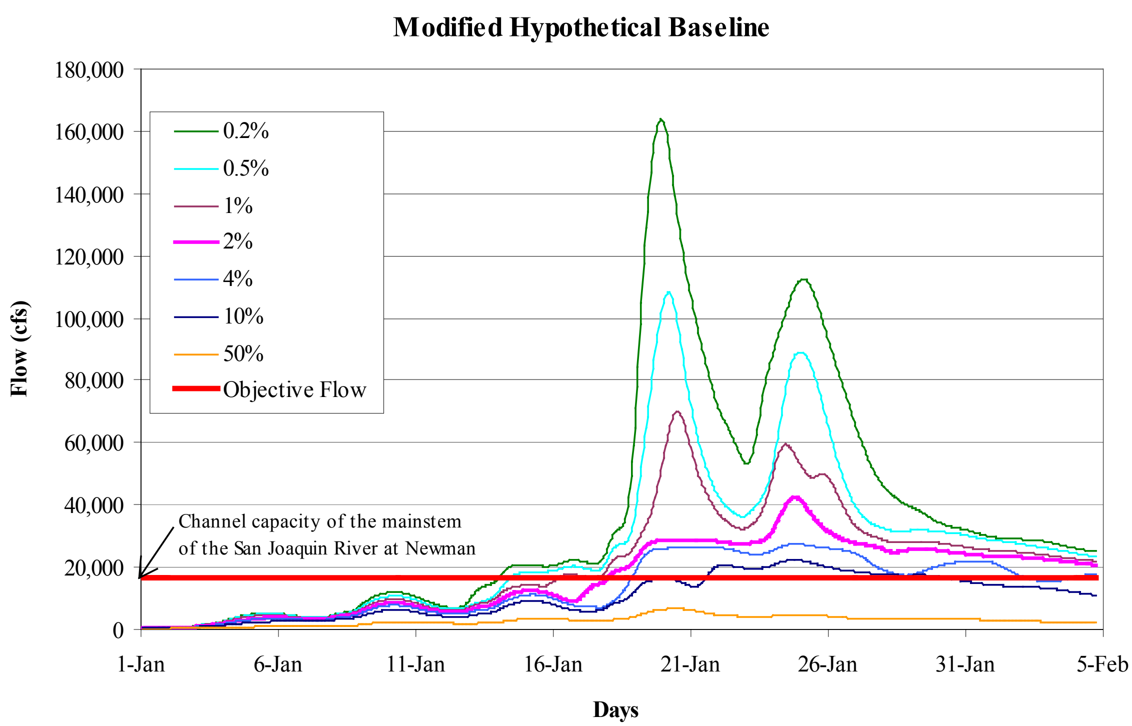
## Comparison of Baseline and Modified Baseline (with-Floodplain Storage) Flow Hydrographs

### San Joaquin River Flow at Newman (Newman Storm Centering)

### Figure VI-14




### Figure VI-15

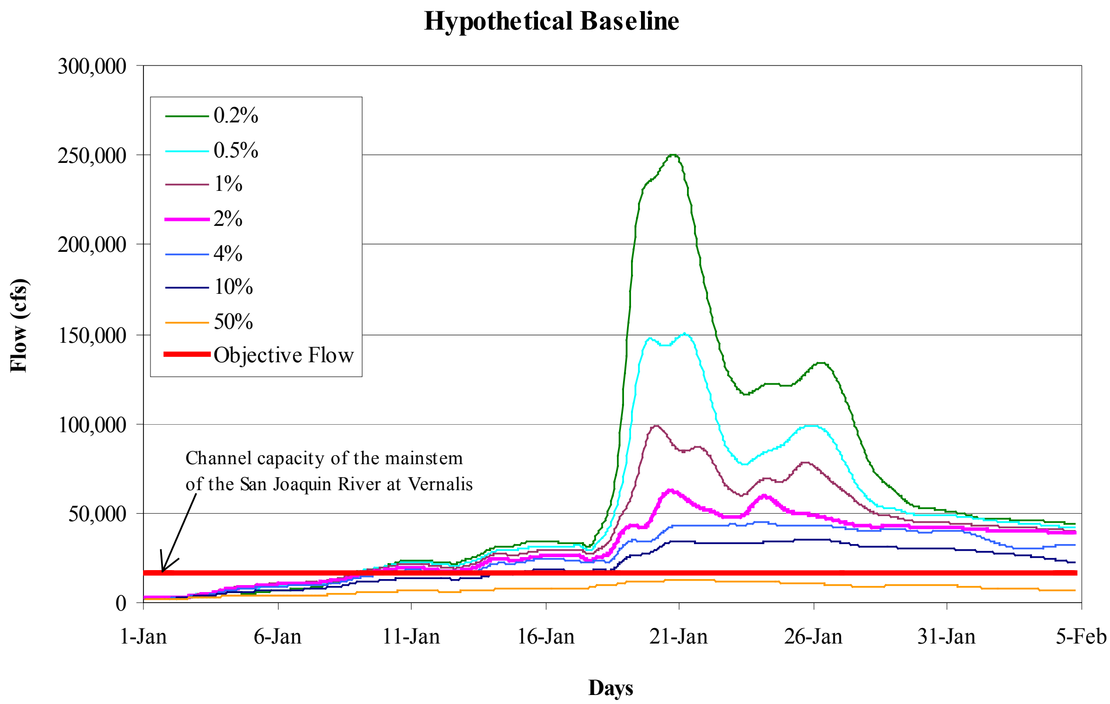



*Note: Prior to use and application, reference the "Expectations of Use" preface.*

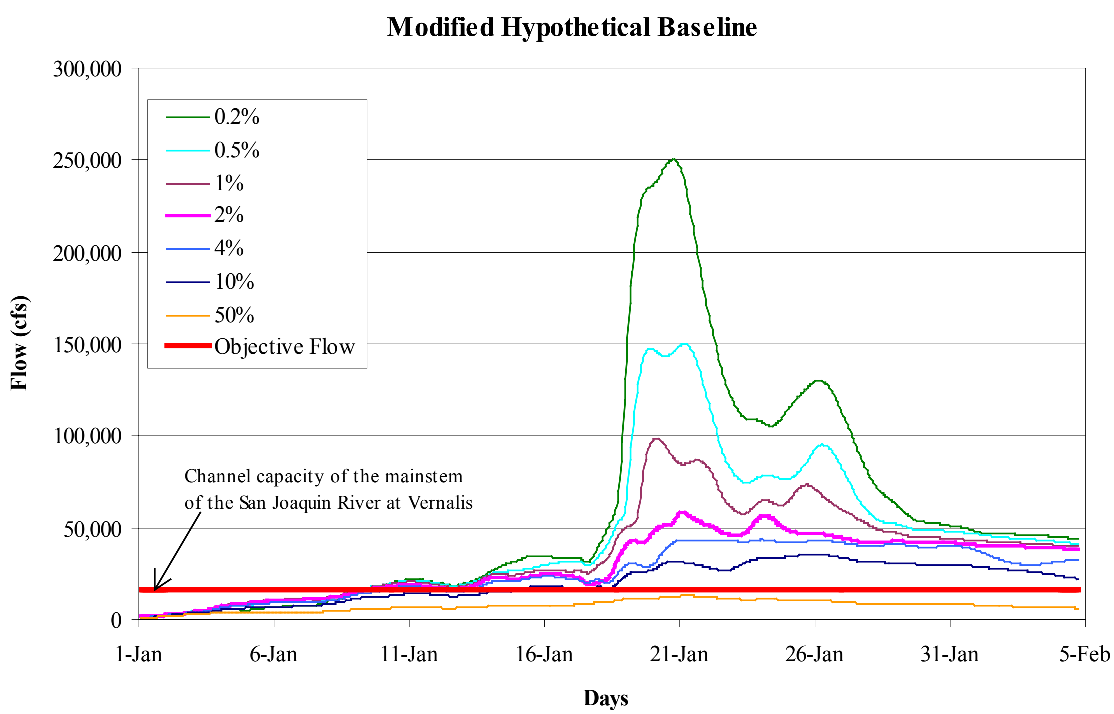
### COMPARISON OF BASELINE AND MODIFIED BASELINE (WITH-FLOODPLAIN STORAGE) FLOW HYDROGRAPHS

### SAN JOAQUIN RIVER FLOW AT VERNALIS (VERNALIS STORM CENTERING)

### FIGURE VI-16

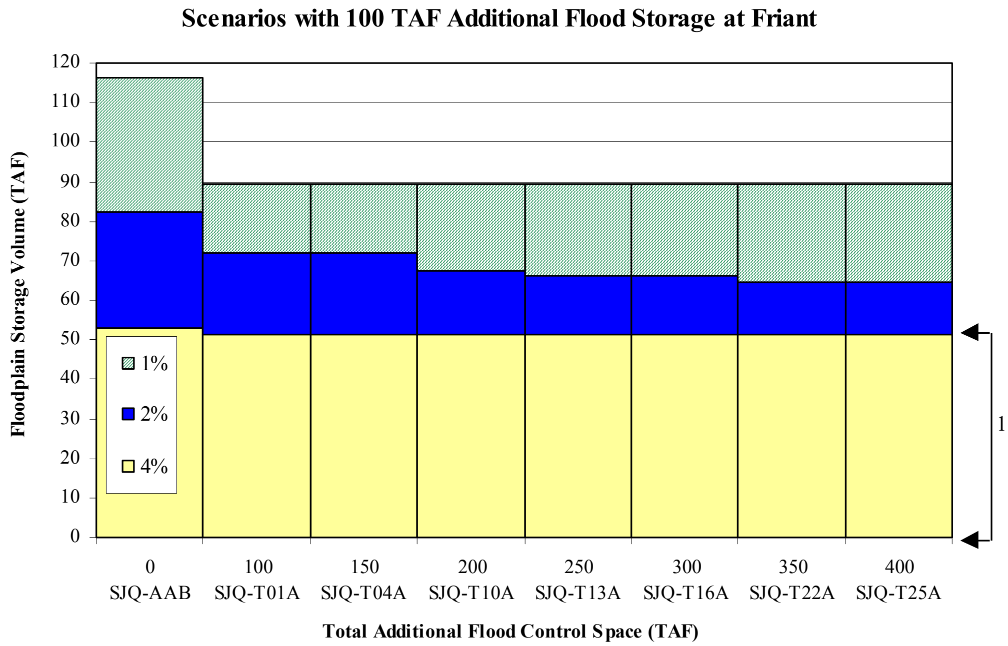


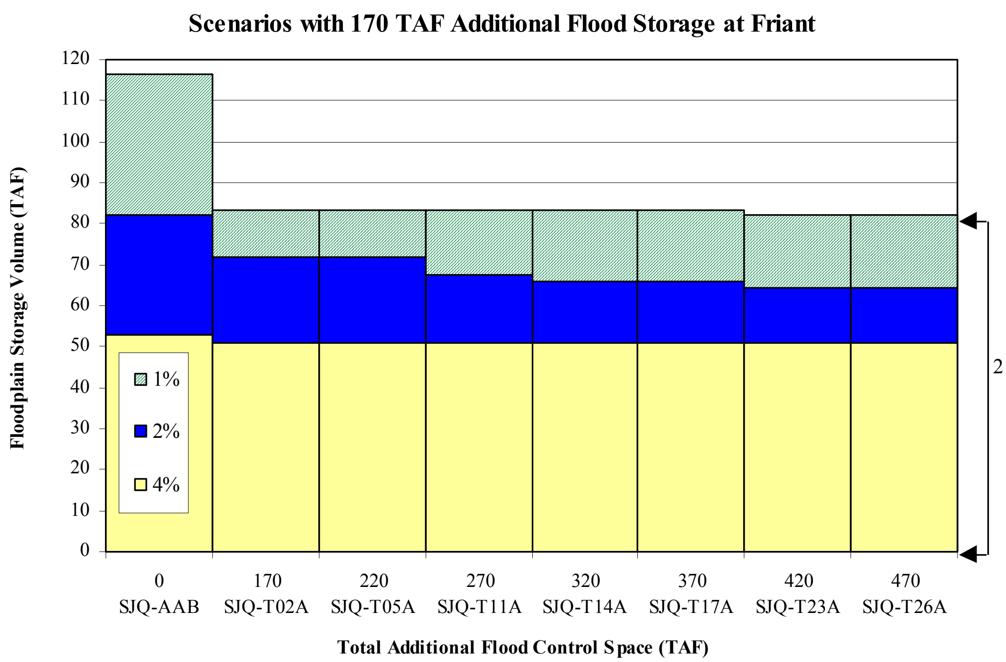

### FIGURE VI-17




*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## FIGURE VI-18 - TOTAL FLOODPLAIN STORAGE VOLUMES FOR FRIANT STORAGE SCENARIOS




*Notes:*

1. *Individual column segments, representative of each alternative scenario, represent the average volume captured by all the floodplain storage basins in all four event centerings, for each of the seven exceedence frequency events.*
2. *Total column heights are not cumulative and are stacked in front of one another (i.e. the average volume associated with the annual 1-percent chance exceedence event is that of the total bar height).*
3. *The Total Additional Flood Control Space (TAF) values are the total additional flood space at Friant, New Don Pedro, and New Exchequer (combined) as modeled in each scenario (see Table VI-6).*

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

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# CHAPTER VII

# OPERATIONS OF HEADWATER RESERVOIRS

## INTRODUCTION

Forty-six headwater reservoirs were included in Comprehensive Study models. Baseline investigations showed that, despite having no formal flood damage reduction functions (operated primarily for water supply and hydropower generation), these reservoirs significantly reduce peak inflows to lower basin reservoirs (see Chapter V). As important elements in system-wide flood hydrology, headwater reservoirs offer opportunities to further reduce potentially damaging flows through reservoir reoperation. This chapter discusses a screening procedure used to highlight opportunities and preliminary alternatives that may provide additional flood damage reduction benefits.

## SCREENING OF HEADWATER RESERVOIRS

Early in the alternatives analysis process, selection criteria were developed to screen headwater reservoirs with promise to reduce flood flows. Reservoirs that did not spill during baseline simulations of the 0.2-percent chance exceedence event, or that are located in series above such reservoirs, were omitted from consideration.

### Criteria

The following criteria were used for all headwater reservoirs:

1) Size. The total storage capacity of a reservoir is proportional to how much flood volume can be stored. Reservoir gross pool storage ranged from 4.5 TAF at Mountain Meadows Reservoir to 1,308 TAF at Lake Almanor with a median of 64 TAF. Almanor was by far the largest; Hetch Hetchy Reservoir followed at 360 TAF. Gross pool storages are tabulated in Chapter II, Table II-1. Reservoirs were assigned values ranging linearly from 0 to 10 according to gross pool storage between 0 TAF and 360 TAF (i.e., gross pool storage of 180 TAF would receive a 5). Lake Almanor did not spill during simulation of the 0.2-percent chance exceedence event and is therefore eliminated from this list.
2) Percent natural runoff regulated. The percent regulation is proportional to the opportunity for reduction of flood flows downstream. Values ranged from 1 to 98 percent (see Chapter III). Reservoirs were assigned values linearly from 0 to 10 according to percent regulation between 0 and 100 percent.
3) Percent capacity at start of simulation. This measure was proportional to the opportunity for reduction of flood flows because reservoirs that tend to maintain near full pools are likely to be more receptive to operations with seasonally reduced storage. Percent capacities ranged from 2 to 100 percent and reservoirs were assigned values between 0 and 10 (i.e., 100 percent capacity would receive a 10).

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4) Level of protection of the lower basin. This measure was inversely proportional to the opportunity to reduce flood flows. In other words, if the lower basin protection is already high, there is less of a need to improve or further reduce flood flows. Baseline levels of protection ranged from 5 percent to approximately 0.58 percent chance exceedences. Values for each reservoir were interpolated along a step-linear scale with the following ordinate pairs (50 percent = 10, 10 percent = 8, 2 percent = 6, 1 percent = 3, 0.5 percent = 1, and 0.2 percent= 0).

5) Level of protection of the headwater reservoir. This measure was also inversely proportional to the opportunity to reduce flood flows; the greater the baseline level of protection, the smaller the opportunity to further reduce flood flows. Baseline levels ranged from less than a 50- to 0.2-percent chance exceedences and values for each reservoir were interpolated based on the scale listed for criterion 4.

## Ranking

In order to focus alternatives analysis on facilities with potential to improve the flood damage reduction system in the Central Valley, criteria values were weighted, summed, and ranked for the headwater reservoirs. Ranked sets were prepared to address: 1) the overall potential of individual facilities to reduce valley flood damages; 2) potential to reduce flood flows; and 3) potential to change operations and the need for that change.

### *Potential Reduction of Valley Flood Damages (Criteria No. 1, 2, 3, 4, & 5)*

This list included all criteria using the most complete perspective while highlighting promising reservoirs (Table VII-1). Criteria values were weighted prior to aggregation and ranking. Size, % regulation, and the lower basin level of protection were emphasized.

### *Potential to Reduce Flood Flows (Criteria No. 1 & 2)*

This list ranked only the physical capabilities of the headwater reservoirs to reduce flows. No attention was given to the need for reductions or for the potential for reoperation to significantly change flood flows. Only size and % regulation criteria, with size weighted twice as heavily as % regulation, were summed and ranked (Table VII-2).

### *Potential to Change Operations and the Need for that Change (Criteria No. 3, 4, & 5)*

This list included % capacity and the level of protection criteria for both headwaters and lower basins (Table VII-3). Of the three, the % capacity at start of simulation received the highest weighting because it most closely reflected the potential to change. Headwater level of protection, which indirectly reflects this same potential, received the lowest rating in order to maintain a balance between the potential for change and the need for that change.

## Viewing the Lists

Rankings provide direction for modelers and planners and can be instructive for people becoming familiar with the operation and function of headwater reservoirs. This exercise is not intended to focus attention and resources on only the highest-ranking facilities and should, therefore, only be used as a rough guide in the formulation of final decisions.

Each list presents a different aspect for consideration during plan formulation and tracking facilities from list to list can be informative. Consider Hetch Hetchy Reservoir, located in the upper Tuolumne River Basin. Hetch Hetchy tops Tables VII-1 and VII-2 and ranks well in Table VII-3. This reservoir places highly across the board indicating that it is strong and well rounded in all criteria. Sly Park Reservoir, which tops the third list, is also an interesting case. Sly Park is located in the Cosumnes River Basin, operated primarily for water supply, and maintained near full (and spills commonly) during wet periods. The Cosumnes River is one of the only Central Valley rivers without a major impoundment on its mainstem and downstream levee systems offering protection against event lesser in magnitude than a 5-percent chance exceedence event. All of these factors suggest that there is need and potential for change in Sly Park operations, which leads to a high rating in Table VII-3. However, Table VII-2 reveals that Sly Park is not likely to be an effective contributor in flood damage reduction due to a low potential to reduce flood flows. Therefore, despite need and potential for change, Sly Park lacks the physical ability to improve flood damage reduction and is a poor candidate for study.

Again, care should be taken to avoid using these lists too explicitly. Rankings are best viewed in terms of fuzzy ranges such as good, borderline, and unlikely candidates.

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## TABLE VII-1

## WEIGHTED MEASURE OF HEADWATER RESERVOIRS POTENTIAL TO REDUCE VALLEY FLOOD DAMAGES

| Rank | Aggregate Measure | Reservoir | Basin | Tributary | Owner |
|---|---|---|---|---|---|
| 1 | 72.9 | Hetch Hetchy | Tuolumne River | Tuolumne Creek | CCSF |
| 2 | 62.5 | Camp Far West | Bear River | Bear River | SSWD |
| 3 | 55.5 | Almanor | Feather River | Nfk Feather Creek | PGE |
| 4 | 54.8 | Cherry Valley | Tuolumne River | Cherry Creek | CCSF |
| 5 | 47.2 | Union Valley | American River | Silver Creek | SMUD |
| 6 | 44.5 | Mammoth Pool | SJQ above Friant | San Joaquin River | SCE |
| 7 | 44.4 | Redinger | SJQ above Friant | San Joaquin River | SCE |
| 8 | 43.6 | Rollins | Bear River | Bear River | NID |
| 9 | 41.4 | Salt Springs | Mokelumne River | Nfk Mokelumne River | PGE |
| 10 | 41.0 | Courtright and Wishon | Kings River | Nfk Kings River | PGE |
| 11 | 39.6 | Stony Gorge | Stony Creek | Stony Creek | USBR |
| 12 | 38.0 | Hell Hole | American River | Rubicon River | PCWA |
| 13 | 36.8 | Sly Park Reservoir | Cosumnes River | Sly Park Creek | USBR |
| 14 | 35.6 | Pit7 | Sac above Shasta | Pit River | PGE |
| 15 | 35.2 | East Park | Stony Creek | Little Stony Creek | USBR |
| 16 | 33.9 | Shaver | SJQ above Friant | Stevenson Creek | SCE |
| 17 | 33.6 | Britton (Pit3) | Sac above Shasta | Pit River | PGE |
| 18 | 32.9 | New Spicer Meadows | Stanislaus River | Highland Creek | CCWD |
| 19 | 32.9 | Pit6 | Sac above Shasta | Pit River | PGE |
| 20 | 31.8 | Edison | SJQ above Friant | Mono Creek | SCE |
| 21 | 31.5 | Beardsley | Stanislaus River | Mfk Stanislaus River | Oakdale - Tri-dams |
| 22 | 30.8 | Spaulding | Yuba River | Sfk Jackson Creek | PGE |
| 23 | 29.5 | French Meadows | American River | Mfk American River | PCWA |
| 24 | 28.2 | Little Grass Valley | Feather River | Sfk Feather River | OWID |
| 25 | 27.8 | Huntington | SJQ above Friant | Big Creek | SCE |
| 26 | 27.5 | Lake Eleanor | Tuolumne River | Eleanor Creek | CCSF |
| 27 | 27.1 | Merle Collins | Yuba River | Dry Creek | Browns Valley ID |
| 28 | 26.5 | Bass Lake | SJQ above Friant | Nfk San Joaquin River | PGE |
| 29 | 26.0 | McCloud | Sac above Shasta | McCloud River | PGE |
| 30 | 25.3 | Scotts Flat | Yuba River | Deer Creek | NID |
| 31 | 23.2 | Bucks Lake | Feather River | Bucks Creek | PGE |
| 32 | 22.9 | Sly Creek | Feather River | Lost Creek | OWID |
| 33 | 22.5 | Donnells | Stanislaus River | Mfk Stanislaus River | Oakdale - Tri-dams |
| 34 | 22.3 | Florence | SJQ above Friant | Sfk San Joaquin River | SCE |
| 35 | 22.3 | Frenchman | Feather River | Last Chance Creek | DWR |

Notes:

Weighting is an aggregate of gross pool storage (six), % flood volume regulated (three), level of basin protection (two), level of headwater protection (one), and percent filled at start of flood (one).

Ranking of headwater reservoirs is based on potential to reduce valley flood damages. Shaded rows indicate facilities that have, or occur above reservoirs that offer protection against events > 0.2-percent chance exceedence.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE VII-1 (CONT.)

## WEIGHTED MEASURE OF HEADWATER RESERVOIRS POTENTIAL TO REDUCE VALLEY FLOOD DAMAGES

| Rank | Aggregate Measure | Reservoir | Basin | Tributary | Owner |
|---|---|---|---|---|---|
| 36 | 21.8 | Butt Valley | Feather River | Butt Creek | PGE |
| 37 | 21.6 | Lower Bear | Mokelumne River | Bear River | PGE |
| 38 | 21.5 | Jackson Meadows | Yuba River | Mfk Yuba River | NID |
| 39 | 20.6 | Lake Davis | Feather River | Big Grizzly Creek | DWR |
| 40 | 19.9 | Antelope | Feather River | Indian Creek | DWR |
| 41 | 18.3 | Mountain Meadows | Feather River | Hamilton Creek | PGE |
| 42 | 17.6 | Loon Lake | American River | Gerle Creek | SMUD |
| 43 | 17.2 | Bowman | Yuba River | Canyon Creek | NID |
| 44 | 15.6 | Ice House | American River | Sfk Silver Creek | SMUD |
| 45 | 13.8 | Fordyce | Yuba River | Fordyce Creek | PGE |

Notes:

Weighting is an aggregate of gross pool storage (six), % flood volume regulated (three), level of basin protection (two), level of headwater protection (one), and percent filled at start of flood (one).

Ranking of headwater reservoirs is based on potential to reduce valley flood damages. Shaded rows indicate facilities that have, or occur above reservoirs that offer protection against events > 0.2-percent chance exceedence.

## TABLE VII-2

## MEASURE OF HEADWATER RESERVOIRS POTENTIAL TO REDUCE FLOOD FLOWS

| Rank | Poser 1 Measure | Reservoir | Basin | Tributary | Owner |
|---|---|---|---|---|---|
| 1 | 73.3 | Hetch Hetchy | Tuolumne River | Tuolumne Creek | CCSF |
| 2 | 69.7 | Almanor | Feather River | Nfk Feather Creek | PGE |
| 3 | 54.6 | Cherry Valley | Tuolumne River | Cherry Creek | CCSF |
| 4 | 51.7 | Camp Far West | Bear River | Bear River | SSWD |
| 5 | 48.0 | Courtright and Wishon | Kings River | Nfk Kings River | PGE |
| 6 | 44.3 | Union Valley | American River | Silver Creek | SMUD |
| 7 | 39.9 | Hell Hole | American River | Rubicon River | PCWA |
| 8 | 38.8 | Mammoth Pool | SJQ above Friant | San Joaquin River | SCE |
| 9 | 36.7 | New Spicer Meadows | Stanislaus River | Highland Creek | CCWD |
| 10 | 35.3 | Salt Springs | Mokelumne River | Nfk Mokelumne River | PGE |
| 11 | 26.6 | Redinger | SJQ above Friant | San Joaquin River | SCE |
| 12 | 26.3 | French Meadows | American River | Mfk American River | PCWA |
| 13 | 26.1 | Shaver | SJQ above Friant | Stevenson Creek | SCE |
| 14 | 24.2 | Rollins | Bear River | Bear River | NID |
| 15 | 24.1 | Edison | SJQ above Friant | Mono Creek | SCE |
| 16 | 23.8 | Spaulding | Yuba River | Sfk Jackson Creek | PGE |
| 17 | 22.7 | Beardsley | Stanislaus River | Mfk Stanislaus River | Oakdale - Tri-dams |
| 18 | 22.5 | Pit7 | Sac above Shasta | Pit River | PGE |
| 19 | 20.4 | Britton (Pit3) | Sac above Shasta | Pit River | PGE |
| 20 | 20.3 | Stony Gorge | Stony Creek | Stony Creek | USBR |
| 21 | 19.7 | Bucks Lake | Feather River | Bucks Creek | PGE |
| 22 | 18.7 | Pit6 | Sac above Shasta | Pit River | PGE |
| 23 | 18.1 | Huntington | SJQ above Friant | Big Creek | SCE |
| 24 | 17.9 | Little Grass Valley | Feather River | Sfk Feather River | OWID |
| 25 | 15.7 | Lake Davis | Feather River | Big Grizzly Creek | DWR |
| 26 | 15.2 | Donnells | Stanislaus River | Mfk Stanislaus River | Oakdale - Tri-dams |
| 27 | 14.5 | Loon Lake | American River | Gerle Creek | SMUD |
| 28 | 14.3 | Florence | SJQ above Friant | Sfk San Joaquin River | SCE |
| 29 | 13.9 | East Park | Stony Creek | Little Stony Creek | USBR |
| 30 | 13.6 | Merle Collins | Yuba River | Dry Creek | Browns Valley Irr Dist |
| 31 | 13.5 | Bowman | Yuba River | Canyon Creek | NID |
| 32 | 12.7 | Sly Creek | Feather River | Lost Creek | OWID |
| 33 | 11.4 | Jackson Meadows | Yuba River | Mfk Yuba River | NID |
| 34 | 11.3 | Lower Bear | Mokelumne River | Bear River | PGE |
| 35 | 10.7 | Fordyce | Yuba River | Fordyce Creek | PGE |

Notes:

Measure based on gross pool storage and percent of basin volume regulated.

Ranking of individual headwater reservoirs is based on potential to reduce flood flows. Shaded rows indicate facilities that have, or occur above reservoirs that offer protection against events > 0.2-percent chance exceedence.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE VII-2 (CONT.)

## MEASURE OF HEADWATER RESERVOIRS POTENTIAL TO REDUCE FLOOD FLOWS

| Rank | Poser 1 Measure | Reservoir | Basin | Tributary | Owner |
|---|---|---|---|---|---|
| 36 | 10.6 | Frenchman | Feather River | Last Chance Creek | DWR |
| 37 | 10.6 | Sly Park Reservoir | Cosumnes River | Sly Park Creek | USBR |
| 38 | 10.1 | Scotts Flat | Yuba River | Deer Creek | NID |
| 39 | 9.9 | Butt Valley | Feather River | Butt Creek | PGE |
| 40 | 9.4 | Bass Lake | SJQ above Friant | Nfk San Joaquin River | PGE |
| 41 | 8.9 | McCloud | Sac above Shasta | McCloud River | PGE |
| 42 | 7.2 | Ice House | American River | Sfk Silver Creek | SMUD |
| 43 | 7.0 | Lake Eleanor | Tuolumne River | Eleanor Creek | CCSF |
| 44 | 4.5 | Antelope | Feather River | Indian Creek | DWR |
| 45 | 1.2 | Mountain Meadows | Feather River | Hamilton Creek | PGE |

Notes:

Measure based on gross pool storage and percent of basin volume regulated.

Ranking of individual headwater reservoirs is based on potential to reduce flood flows. Shaded rows indicate facilities that have, or occur above reservoirs that offer protection against events > 0.2-percent chance exceedence.

# TABLE VII-3

## MEASURE OF HEADWATER RESERVOIRS POTENTIAL TO CHANGE OPERATIONS AND NEED FOR THAT CHANGE

| Rank | Posers 2-3 Measure | Reservoir | Basin | Tributary | Owner |
|---|---|---|---|---|---|
| 1 | 91.5 | Sly Park Reservoir | Cosumnes River | Sly Park Creek | USBR |
| 2 | 91.3 | Rollins | Bear River | Bear River | NID |
| 3 | 90.2 | Camp Far West | Bear River | Bear River | SSWD |
| 4 | 89.6 | Redinger | SJQ above Friant | San Joaquin River | SCE |
| 5 | 88.8 | Stony Gorge | Stony Creek | Stony Creek | USBR |
| 6 | 88.8 | East Park | Stony Creek | Little Stony Creek | USBR |
| 7 | 76.7 | Pit6 | Sac above Shasta | Pit River | PGE |
| 8 | 76.7 | Pit7 | Sac above Shasta | Pit River | PGE |
| 9 | 75.6 | McCloud | Sac above Shasta | McCloud River | PGE |
| 10 | 73.9 | Hetch Hetchy | Tuolumne River | Tuolumne Creek | CCSF |
| 11 | 72.9 | Britton (Pit3) | Sac above Shasta | Pit River | PGE |
| 12 | 72.3 | Scotts Flat | Yuba River | Deer Creek | NID |
| 13 | 71.2 | Mountain Meadows | Feather River | Hamilton Creek | PGE |
| 14 | 70.4 | Lake Eleanor | Tuolumne River | Eleanor Creek | CCSF |
| 15 | 68.3 | Merle Collins | Yuba River | Dry Creek | Browns Valley ID |
| 16 | 66.0 | Antelope | Feather River | Indian Creek | DWR |
| 17 | 64.8 | Union Valley | American River | Silver Creek | SMUD |
| 18 | 61.7 | Bass Lake | SJQ above Friant | Nfk San Joaquin River | PGE |
| 19 | 59.3 | Little Grass Valley | Feather River | Sfk Feather River | OWID |
| 20 | 58.8 | Butt Valley | Feather River | Butt Creek | PGE |
| 21 | 58.7 | Cherry Valley | Tuolumne River | Cherry Creek | CCSF |
| 22 | 56.6 | Shaver | SJQ above Friant | Stevenson Creek | SCE |
| 23 | 56.5 | Frenchman | Feather River | Last Chance Creek | DWR |
| 24 | 56.1 | Sly Creek | Feather River | Lost Creek | OWID |
| 25 | 55.7 | Beardsley | Stanislaus River | Mfk Stanislaus River | Oakdale - Tri-dams |
| 26 | 53.7 | Jackson Meadows | Yuba River | Mfk Yuba River | NID |
| 27 | 51.8 | Huntington | SJQ above Friant | Big Creek | SCE |
| 28 | 51.3 | Edison | SJQ above Friant | Mono Creek | SCE |
| 29 | 48.8 | Spaulding | Yuba River | Sfk Jackson Creek | PGE |
| 30 | 46.2 | Salt Springs | Mokelumne River | Nfk Mokelumne River | PGE |
| 31 | 45.9 | Ice House | American River | Sfk Silver Creek | SMUD |
| 32 | 44.8 | Mammoth Pool | SJQ above Friant | San Joaquin River | SCE |
| 33 | 43.4 | Hell Hole | American River | Rubicon River | PCWA |
| 34 | 43.1 | Lake Davis | Feather River | Big Grizzly Creek | DWR |
| 35 | 42.6 | Lower Bear | Mokelumne River | Bear River | PGE |

Notes:

Measure based on level of protection for the basin, level of protection for the reservoir, and percent filled at start of flood.

Ranking of individual headwater reservoirs based on potential to change operations and need for that change.
Shaded rows indicate facilities that offer protection against events > 0.2-percent chance exceedence.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE VII-3 (CONT.)

## MEASURE OF HEADWATER RESERVOIRS POTENTIAL TO CHANGE OPERATIONS AND NEED FOR THAT CHANGE

| Rank | Posers 2-3 Measure | Reservoir | Basin | Tributary | Owner |
|---|---|---|---|---|---|
| 36 | 40.9 | French Meadows | American River | Mfk American River | PCWA |
| 37 | 40.1 | Bucks Lake | Feather River | Bucks Creek | PGE |
| 38 | 37.9 | Bowman | Yuba River | Canyon Creek | NID |
| 39 | 37.7 | Donnells | Stanislaus River | Mfk Stanislaus River | Oakdale - Tri-dams |
| 40 | 37.5 | Almanor | Feather River | Nfk Feather Creek | PGE |
| 41 | 34.2 | Loon Lake | American River | Gerle Creek | SMUD |
| 42 | 30.7 | Courtright and Wishon | Kings River | Nfk Kings River | PGE |
| 43 | 30.5 | New Spicer Meadows | Stanislaus River | Highland Creek | CCWD |
| 44 | 27.6 | Florence | SJQ above Friant | Sfk San Joaquin River | SCE |
| 45 | 24.7 | Fordyce | Yuba River | Fordyce Creek | PGE |

Notes:

Measure based on level of protection for the basin, level of protection for the reservoir, and percent filled at start of flood.

Ranking of individual headwater reservoirs based on potential to change operations and need for that change.
Shaded rows indicate facilities that offer protection against events > 0.2-percent chance exceedence.

## ALTERNATIVES ANALYSIS FOR HEADWATER SPILLWAYS

The majority of headwater reservoirs are owned and operated by private agencies for hydropower generation and water supply. Preferred alternatives increase flood reduction without impinging on existing operations. Plan formulation should begin by identifying such alternatives, as these are most likely to receive support from local and regional interests. In the headwater drainage basins, a promising group of alternatives involves using spillway regulation to further attenuate peak flood flows.

### Spillway Analysis

Gated operations at flood damage reduction reservoirs are typically guided by Emergency Spillway Release Diagrams (ESRD). These diagrams script reservoir releases as a function of inflow (or rate of water surface elevation rise) and pool elevation. ESRD operations activate only when flood conditions threaten to surpass the existing flood management capabilities of a reservoir. This occurs only near the top of the reservoir and in no way impacts operations in the water conservation pool.

Headwater reservoirs outfitted with gates and ESRD criteria would further attenuate flood volumes during extreme events, which could, in turn, reduce inflows to lower basin reservoirs during critical flood times.

#### *Current Spillway Operations*

Spillway operations of all studied headwater reservoirs can be sorted into three groups: 1) unimpaired; 2) impaired with seasonal restrictions; and 3) impaired without seasonal restrictions (Table VII-4). Spillways are impaired with a variety of devices, including flashboards and radial, tainter, and drum gates. At some reservoirs, the California State Division of Safety of Dams (DSOD) restricts the use of impairments during the rain flood season due to safety and accessibility concerns. When spillways are impaired and unrestricted, owners and operators largely determine how the gates are used.

Division of Safety of Dams restrictions are implemented in the Fall and terminate in early Spring (April 1 through May 1). In some cases, restrictions may be disengaged earlier pending low snowmelt forecasts and DSOD approval.

#### *Alternative Operations*

There are different strategies for using spillway regulation to reduce flood flows (i.e., implementation of ESRD criteria for headwater reservoirs for all storage in excess of gross pool or hold gates open until operations are triggered by dangerous conditions at the downstream flood damage reduction reservoir). The primary danger in all cases is exhaustion of available surcharge storage prior to the flood peak, which would lead to releases in excess of the peak reservoir outflows that would have occurred with an unimpaired spillway. Emergency spillway release criteria can be scripted to minimize this danger, but it is a risk.

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# TABLE VII-4

## SUMMARY OF STUDIED HEADWATER RESERVOIRS

| Reservoir | Tributary | Owner | Type [a] | Impaired Spillway | Seasonal Restrictions | Gate Type | # Gates | Gate Width (feet) | Gate Height (feet) | Induced Storage Potential[c] | What To Do |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sacramento River above Shasta** | | | | | | | | | | | |
| ***Britton (Pit3)*** | Pit River | PGE | 2 | Yes | Yes | Inflatable | 3 | 84.6 | 6 | Overtop < 4 % | Omit |
| ***Pit6*** | Pit River | PGE | 3 | Yes | No | Radial | 2 | 49 | 40 | overtop < 50% | Omit |
| ***Pit7*** | Pit River | PGE | 3 | Yes | No | Radial | 2 | 49 | 40 | overtop < 10% | Omit |
| ***McCloud*** | McCloud River | PGE | 3 | Yes | No | Radial | 3 | 27 | 24.5 | good, but gates in use | Consider |
| **Stony Creek above Black Butte** | | | | | | | | | | | |
| ***East Park*** | Little Stony Creek | USBR | 2 | Yes | Yes | F.boards | 9 | 46 | 1.5 | overtop < 2% | Omit |
| ***Stony Gorge*** | Stony Creek | USBR | 2[b] | Yes | Yes | Slide Gates | 3 | 30 | 30 | good | Consider |
| **Feather River above Oroville** | | | | | | | | | | | |
| ***Mountain Meadows*** | Hamilton Creek | PGE | 2 | Yes | Yes | F.boards | 22 | 8 | 4.54 | Not important | Omit |
| ***Almanor*** | Nfk Feather Creek | PGE | 1 | No | -- | -- | -- | -- | -- | Not important | Omit |
| ***Butt Valley*** | Butte Creek | PGE | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Antelope*** | Indian Creek | DWR | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Bucks Lake*** | Bucks Creek | PGE | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Frenchman*** | Last Chance Creek | DWR | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Lake Davis*** | Big Grizzly Creek | DWR | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Little Grass Valley*** | Sfk Feather River | OWID | 2 | Yes | Yes | Radial | 2 | 40 | 15 | good | Consider |
| ***Sly Creek*** | Lost Creek | OWID | 2 | Yes | Yes | Radial | 1 | 54 | 16 | good | Consider |

a: Type: 1) unimpaired; 2) Impaired with seasonal restrictions; and 3) impaired without seasonal restrictions.

b: Stony Gorge gates are in operation during winter months but storage is restricted to 38,311 acre-feet.

c: Value represents that event occurring less in frequency than the stated percent chance exceedence event.

## TABLE VII-4 (CONT.)

## SUMMARY OF STUDIED HEADWATER RESERVOIRS

| Reservoir | Tributary | Owner | Type [a] | Impaired Spillway | Seasonal Restrictions | Gate Type | # Gates | Gate Width (feet) | Gate Height (feet) | Induced Storage Potential[c] | What To Do |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Yuba above Marysville** | | | | | | | | | | | |
| ***Jackson Meadows*** | Mfk Yuba River | NID | 2 | Yes | Yes | Radial | 3 | 30 | 15 | good | Consider |
| ***Bowman*** | Canyon Creek | NID | 2 | Yes | Yes | Radial | 7 | 12 | 5.8 | good | Omit |
| ***Fordyce*** | Fordyce Creek | PGE | 2 | Yes | Yes | Radial | 2 | 14 | 15 | do not exceed | Consider |
| ***Spaulding*** | Sfk Jackson Creek | PGE | 2 | Yes | Yes | Radial | 3 | 14 | 20 | do not exceed | Consider |
| ***Scotts Flat*** | Deer Creek | NID | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Merle Collins*** | Dry Creek | BVID | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| **Bear** | | | | | | | | | | | |
| ***Rollins*** | Bear River | NID | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Camp Far West*** | Bear River | SSWD | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| **American** | | | | | | | | | | | |
| ***French Meadows*** | Mfk American River | PCWA | 2 | Yes | Yes | Radial | 2 | 20 | 18.5 | good | Consider |
| ***Hell Hole*** | Rubicon River | PCWA | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Loon Lake*** | Gerle Creek | SMUD | 1 | No | -- | -- | -- | -- | -- | good | Omit |
| ***Union Valley*** | Silver Creek | SMUD | 2 | Yes | Yes | Radial | 2 | 40 | 15 | good | Consider |
| ***Ice House*** | Sfk Silver Creek | SMUD | 2 | Yes | Yes | Radial | 2 | 40 | 14 | good | Consider |
| **Cosumnes above Michigan Bar** | | | | | | | | | | | |
| ***Sly Park Reservoir*** | Sly Park Creek | USBR | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| **Mokelumne above Pardee** | | | | | | | | | | | |
| ***Salt Springs*** | Nfk Mokelumne River | PGE | 2 | Yes | Yes | Radial | 11 | 40 | 11 | good | Consider |
| ***Lower Bear*** | Bear River | PGE | 2 | Yes | Yes | Radial | 1 | 8 | 14 | good | Consider |

a: Type: 1) unimpaired; 2) Impaired with seasonal restrictions; and 3) impaired without seasonal restrictions.

b: Stony Gorge gates are in operation during winter months but storage is restricted to 38,311 acre-feet.

c: Value represents that event occurring less in frequency than the stated percent chance exceedence event.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE VII-4 (CONT.)

## SUMMARY OF STUDIED HEADWATER RESERVOIRS

| Reservoir | Tributary | Owner | Type [a] | Impaired Spillway | Seasonal Restrictions | Gate Type | # Gates | Gate Width (feet) | Gate Height (feet) | Induced Storage Potential[c] | What To Do |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stanislaus above New Melones** | | | | | | | | | | | |
| ***New Spicer Meadows*** | Highland Creek | CCWD | 1 | No | -- | -- | -- | -- | -- | good | Omit |
| ***Donnells*** | Mfk Stanislaus River | Oak-dale - Tri-dams | 2 | Yes | Yes | Radial | 5 | 35 | 19 | good | Consider |
| ***Beardsley*** | Mfk Stanislaus River | Oak-dale - Tri-dams | 2 | Yes | Yes | Radial | 4 | 40 | 30 | good | Consider |
| **Tuolumne above Don Pedro** | | | | | | | | | | | |
| ***Hetch Hetchy*** | Tuolumne Creek | CCSF | 2 | Yes | Yes | Drum | 3 | 66 | 10 | good | Consider |
| ***Lake Eleanor*** | Eleanor Creek | CCSF | 2 | Yes | Yes | F.boards | 25 | 8 | 4 | overtop > 10% | Omit |
| ***Cherry Valley*** | Cherry Creek | CCSF | 2 | Yes | Yes | F.boards | -- | -- | -- | good | Consider |
| **San Joaquin above Friant** | | | | | | | | | | | |
| ***Florence*** | Sfk San Joaquin River | SCE | 3 | Yes | No | Drum | 2 | 51 | 12 | good, but gates in use | Consider |
| ***Edison*** | Mono Creek | SCE | 3 | Yes | No | Radial | 1 | 15 | 8 | good, but gates in use | Omit |
| ***Mammoth Pool*** | San Joaquin River | SCE | 1 | No | -- | -- | -- | -- | -- | good | Consider |
| ***Huntington*** | Big Creek | SCE | 3 | Yes | No | Radial | 15 | 12 | 5 | good, but gates in use | Consider |
| ***Shaver*** | Stevenson Creek | SCE | 1 | No | -- | -- | -- | -- | -- | good | Omit |
| ***Redinger*** | San Joaquin River | SCE | 3 | Yes | No | Radial | 4 | 40 | 30 | good, but gates in use | Consider |
| ***Bass Lake*** | Nfk San Joaquin River | PGE | 2 | Yes | Yes | Radial | 2 | 17.58 | 10.75 | good | Consider |
| **Kings River above Pine Flat** | | | | | | | | | | | |
| ***Wishon*** | Nfk Kings River | PGE | 2 | Yes | Yes | Radial | 6 | 40 | 11.5 | good | Consider |

a: Type: 1) unimpaired; 2) Impaired with seasonal restrictions; and 3) impaired without seasonal restrictions.

b: Stony Gorge gates are in operation during winter months but storage is restricted to 38,311 acre-feet.

c: Value represents that event occurring less in frequency than the stated percent chance exceedence event.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

In all cases, maximum design pool elevations must be restricted below top of dam to allow for wind and wave run-up. For the purposes of this feasibility study, a limit of 3 feet below top of dam was assumed during site selection.

Division of Safety of Dams restrictions are due in part to the isolation and inaccessibility of certain dam sites during inclement weather in winter months. Spillway regulation would require remote or automated operations capability. The Water Management Section of the Sacramento District, USACE, has completed dam and computer system retrofitting for remote operations at Farmington and Warm Springs Dams. Water Management estimates that site implementation would require as little as 1 year and $300,000, pending no significant structural modifications.

### *Site Selection*

Baseline investigations based on simulation of the seven synthetic exceedence frequency flood events showed that many of the reservoirs filled beyond safe levels (3' below top of dam) without gated spillway operations. Since gated operations tend to store more water, reservoirs without sufficient capacity to route flows (with unimpaired spillways) are unlikely to further reduce floods through spillway regulation.

Baseline simulations were summarized and peak storages were compared to the maximum storages that would be allowed after spillway regulation (Table VII-5). According to the space available, many facilities did not look like promising candidates. Spillway regulation at some of these sites may become more effective if included as part of a reoperation strategy.

According to space available, volume of spill, and peak outflow, 13 headwater reservoirs were highlighted as candidates (from north to south): 1) Butt Valley; 2) Antelope; 3) Frenchman; 4) Little Grass Valley; 5) Rollins; 6) Camp Far West; 7) French Meadows; 8) Union Valley; 9) Salt Springs; 10) Beardsley; 11) Hetch Hetchy; 12) Cherry Valley; and 13) Mammoth Pool.

### *Conclusions*

Flood hydrology and reservoir operations will need to be studied for any reservoir targeted for spillway regulation. Additionally, ideas such as allocation of water surcharged during the rainflood season to environmental water purposes (pending spring snowmelt forecasts) should be pursued to identify interested parties and gather a wide support base.

Gating of headwater reservoirs offers benefits beyond flood reduction. Some positive and negative effects of added or modified spillway regulation are anticipated. Overall, there is a strong upside to regulating spillways and it is hoped that this concept will receive local interest.

- **Pros**
  - Increased hydropower production via routing more water through penstocks at higher heads.
  - Increased water supply as new spillway gates enlarge storage capacities of existing reservoirs.
  - Owners and operators could utilize remote operations to reduce time and resources expended while making release changes.
  - Many reservoirs have gated spillways that are required to be held full open during the rain flood season. If operational restrictions can be lifted and remote or automated operations established, flood reduction functions at these facilities could be made operational quickly and economically.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

- The Water Management Section of the USACE, in Sacramento, has experience in software and hardware retrofitting for remote operation and could provide expert guidance during implementation.
- Storage accumulated during the rain flood season could be used for environmental purposes including pulse flows designed to stimulate riparian vegetation, flows routed to slow the recession of water surface elevations, volume to enhance waterfowl and wildlife refuge habitat, and freshets (cues for fish migration).
- Structural additions and opportunities to remote operate gates may attract private owners and operators willing to act as local sponsors for individual projects.

• **Cons**

- Significant changes to the operation of headwater reservoirs may reshape the lower basin flood hydrology enough to force existing ESRD criteria to be reviewed.
- The success of gated operation is sensitive to timing within the basin and will need to be addressed during the study.
- Additional spillway regulation would be designed to reduce peak flood flows, which may suppress ecosystem dynamics linked to high river flows.
- May entail structural additions and minor modifications.
- Must consider the risk of exhausting available surcharge storage prior tot he incoming flood volume. This would result in higher outflows than those that would occur under unimpaired spillway operation.

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# TABLE VII-5

# AVAILABLE STORAGE WITHIN HEADWATER RESERVOIRS

| | | | Annual Percent Chance Exceedences | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sacramento River above Shasta** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***Britton*** | | Peak outflow (cfs) | 27,013 | 59,368 | 76,043 | 88,727 | 101,258 | 130,172 | 131,557 |
| | | Peak storage (ac-ft) | 43,496 | 53,388 | 57,812 | 61,187 | 64,359 | 67,333 | 67,393 |
| Storage at proposed TIS (ac-ft) | 54,465 | Space available (ac-ft) | 10,969 | 1,077 | -3,347 | -6,722 | -9,894 | -12,868 | -12,928 |
| Gross pool (ac-ft) | 40,626 | Percent gross pool | 107% | 131% | 142% | 151% | 158% | 166% | 166% |
| | | Volume of spill (ac-ft) | 277,906 | 733,058 | 956,736 | 1,118,210 | 1,275,036 | 1,427,874 | 1,624,853 |
| ***McCloud*** | | Peak outflow (cfs) | 8,291 | 18,293 | 23,566 | 27,461 | 31,686 | 35,962 | 40,667 |
| | | Peak storage (ac-ft) | 27,732 | 31,393 | 32,802 | 33,819 | 34,669 | 35,111 | 35,723 |
| Storage at proposed TIS (ac-ft) | 39,000 | Space available (ac-ft) | 11,268 | 7,607 | 6,198 | 5,181 | 4,331 | 3,889 | 3,277 |
| Gross pool (ac-ft) | 24,500 | Percent gross pool | 113% | 128% | 134% | 138% | 142% | 143% | 146% |
| | | Volume of spill (ac-ft) | 77,378 | 217,796 | 286,742 | 336,560 | 384,945 | 432,118 | 492,957 |
| ***Pit6*** | | Peak outflow (cfs) | 34,714 | 74,914 | 95,627 | 111,386 | 126,393 | 149,724 | 164,089 |
| | | Peak storage (ac-ft) | 16,479 | 17,141 | 17,391 | 17,581 | 17,998 | 19,736 | 20,030 |
| Storage at proposed TIS (ac-ft) | 16,924 | Space available (ac-ft) | 445 | -217 | -467 | -657 | -1,074 | -2,812 | -3,106 |
| Gross pool (ac-ft) | 15,700 | Percent gross pool | 105% | 109% | 111% | 112% | 115% | 126% | 128% |
| | | Volume of spill (ac-ft) | 289,981 | 848,129 | 1,124,508 | 1,324,099 | 1,517,983 | 1,706,962 | 1,950,637 |
| ***Pit7*** | | Peak outflow (cfs) | 37,903 | 81,807 | 104,526 | 121,735 | 138,356 | 162,816 | 179,588 |
| | | Peak storage (ac-ft) | 33,085 | 35,789 | 36,931 | 37,736 | 38,233 | 38,924 | 39,630 |
| Storage at proposed TIS (ac-ft) | 36,429 | Space available (ac-ft) | 3,344 | 640 | -502 | -1,307 | -1,804 | -2,495 | -3,201 |
| Gross pool (ac-ft) | 19,084 | Percent gross pool | 173% | 188% | 194% | 198% | 200% | 204% | 208% |
| | | Volume of spill (ac-ft) | 281,902 | 893,572 | 1,196,374 | 1,415,226 | 1,627,700 | 1,834,765 | 2,101,760 |
| | | **Combined space available** | **26,000** | **9,000** | **6,000** | **5,000** | **4,000** | **4,000** | **3,000** |
| **Stony Creek above Black Butte** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***East Park*** | | Peak outflow (cfs) | 1,572 | 4,978 | 7,119 | 8,862 | 10,762 | 12,854 | 15,636 |
| | | Peak storage (ac-ft) | 50,413 | 52,362 | 53,344 | 54,121 | 54,886 | 55,534 | 56,266 |
| Storage at proposed TIS (ac-ft) | 48,517 | Space available (ac-ft) | -1,896 | -3,845 | -4,827 | -5,604 | -6,369 | -7,017 | -7,749 |
| Gross pool (ac-ft) | 50,899 | Percent gross pool | 99% | 103% | 105% | 106% | 108% | 109% | 111% |
| | | Volume of spill (ac-ft) | 20,704 | 59,295 | 83,220 | 102,289 | 122,087 | 142,612 | 170,711 |
| ***Stony Gorge*** | | Peak outflow (cfs) | 4,440 | 14,617 | 20,929 | 26,100 | 31,777 | 37,677 | 45,958 |
| | | Peak storage (ac-ft) | 38,930 | 45,017 | 47,847 | 50,102 | 52,254 | 54,458 | 57,247 |
| | | Volume of spill (ac-ft) | 61,931 | 177,346 | 248,812 | 305,850 | 365,113 | 426,550 | 510,678 |
| | | **Combined space available** | **15,000** | **9,000** | **7,000** | **4,000** | **2,000** | **0** | **0** |
| **Feather River above Oroville** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***Mountain Meadows*** | | Peak outflow (cfs) | 200 | 903 | 1,322 | 1,726 | 2,325 | 2,915 | 3,453 |
| | | Peak storage (ac-ft) | 4,451 | 8,269 | 10,152 | 11,573 | 12,834 | 13,944 | 15,930 |
| Storage at proposed TIS (ac-ft) | 14,477 | Space available (ac-ft) | 10,026 | 6,208 | 4,325 | 2,904 | 1,643 | 533 | -1,453 |
| Gross pool (ac-ft) | 4,468 | Percent gross pool | 100% | 185% | 227% | 259% | 287% | 312% | 357% |
| | | Volume of spill (ac-ft) | 0 | 8,033 | 14,190 | 19,013 | 23,922 | 28,886 | 35,520 |

Note:
1. The acronym "TIS" refers to "top of induced surcharge". Space Available is equal to Storage at Proposed TIS less Peak Storage.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

## TABLE VII-5 (CONT.)
## AVAILABLE STORAGE WITHIN HEADWATER RESERVOIRS

| Feather River above Oroville (Cont.) | | | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
|---|---|---|---|---|---|---|---|---|---|
| ***Almanor*** | | Peak outflow (cfs) | 2,153 | 2,153 | 3,077 | 4,218 | 4,218 | 4,218 | 4,218 |
| | | Peak storage (ac-ft) | 849,860 | 908,712 | 956,800 | 981,884 | 1,019,947 | 1,060,489 | 1,115,416 |
| Storage at proposed TIS (ac-ft) | 1,716,465 | Space available (ac-ft) | 866,605 | 807,753 | 759,665 | 734,581 | 696,518 | 655,976 | 601,049 |
| Gross pool (ac-ft) | 1,308,000 | Percent gross pool | 65% | 69% | 73% | 75% | 78% | 81% | 85% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Butt Valley*** | | Peak outflow (cfs) | 2,578 | 3,447 | 5,097 | 6,778 | 7,953 | 9,228 | 11,408 |
| | | Peak storage (ac-ft) | 41,265 | 51,594 | 55,376 | 57,041 | 58,698 | 60,356 | 62,029 |
| Storage at proposed TIS (ac-ft) | 70,239 | Space available (ac-ft) | 28,974 | 18,645 | 14,863 | 13,198 | 11,541 | 9,883 | 8,210 |
| Gross pool (ac-ft) | 49,768 | Percent gross pool | 83% | 104% | 111% | 115% | 118% | 121% | 125% |
| | | Volume of spill (ac-ft) | 0 | 4,986 | 16,536 | 26,196 | 36,157 | 46,212 | 59,638 |
| ***Antelope*** | | Peak outflow (cfs) | 426 | 1,215 | 1,694 | 2,109 | 2,758 | 3,501 | 4,481 |
| | | Peak storage (ac-ft) | 22,905 | 24,413 | 25,554 | 26,545 | 27,480 | 28,253 | 29,277 |
| Storage at proposed TIS (ac-ft) | 43,200 | Space available (ac-ft) | 20,295 | 18,787 | 17,646 | 16,655 | 15,720 | 14,947 | 13,923 |
| Gross pool (ac-ft) | 22,000 | Percent gross pool | 104% | 111% | 116% | 121% | 125% | 128% | 133% |
| | | Volume of spill (ac-ft) | 5,964 | 17,539 | 24,032 | 28,993 | 34,007 | 39,061 | 45,810 |
| ***Bucks Lake*** | | Peak outflow (cfs) | 381 | 396 | 396 | 396 | 747 | 1,513 | 3,621 |
| | | Peak storage (ac-ft) | 63,780 | 80,250 | 92,304 | 101,936 | 109,742 | 112,737 | 117,319 |
| Storage at proposed TIS (ac-ft) | 130,400 | Space available (ac-ft) | 66,620 | 50,150 | 38,096 | 28,464 | 20,658 | 17,663 | 13,081 |
| Gross pool (ac-ft) | 108,400 | Percent gross pool | 59% | 74% | 85% | 94% | 101% | 104% | 108% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 2,643 | 12,326 | 25,404 |
| ***Frenchman*** | | Peak outflow (cfs) | 153 | 482 | 1,064 | 1,544 | 2,052 | 2,552 | 3,230 |
| | | Peak storage (ac-ft) | 45,561 | 52,005 | 54,460 | 56,004 | 57,635 | 59,242 | 61,425 |
| Storage at proposed TIS (ac-ft) | 76,400 | Space available (ac-ft) | 30,839 | 24,395 | 21,940 | 20,396 | 18,765 | 17,158 | 14,975 |
| Gross pool (ac-ft) | 49,500 | Percent gross pool | 92% | 105% | 110% | 113% | 116% | 120% | 124% |
| | | Volume of spill (ac-ft) | 0 | 4,532 | 10,009 | 14,231 | 18,843 | 23,610 | 30,051 |
| ***Lake Davis*** | | Peak outflow (cfs) | 193 | 199 | 203 | 206 | 210 | 292 | 467 |
| | | Peak storage (ac-ft) | 60,230 | 68,187 | 73,975 | 78,162 | 82,845 | 86,754 | 90,347 |
| Storage at proposed TIS (ac-ft) | 114,000 | Space available (ac-ft) | 53,770 | 45,813 | 40,025 | 35,838 | 31,155 | 27,246 | 23,653 |
| Gross pool (ac-ft) | 83,000 | Percent gross pool | 73% | 82% | 89% | 94% | 100% | 105% | 109% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 1,148 | 5,059 |
| ***Little Grass Valley*** | | Peak outflow (cfs) | 810 | 2,349 | 3,354 | 4,389 | 5,904 | 7,423 | 9,287 |
| | | Peak storage (ac-ft) | 76,533 | 80,020 | 82,384 | 84,263 | 85,670 | 86,964 | 88,652 |
| Storage at proposed TIS (ac-ft) | 105,000 | Space available (ac-ft) | 28,467 | 24,980 | 22,616 | 20,737 | 19,330 | 18,036 | 16,348 |
| Gross pool (ac-ft) | 74,730 | Percent gross pool | 102% | 107% | 110% | 113% | 115% | 116% | 119% |
| | | Volume of spill (ac-ft) | 11,489 | 34,641 | 47,604 | 57,498 | 67,491 | 77,560 | 91,000 |
| ***Sly Creek*** | | Peak outflow (cfs) | 850 | 850 | 2,995 | 5,218 | 6,883 | 8,405 | 10,379 |
| | | Peak storage (ac-ft) | 49,935 | 53,521 | 59,117 | 60,727 | 61,714 | 62,407 | 63,284 |
| Storage at proposed TIS (ac-ft) | 66,275 | Space available (ac-ft) | 16,340 | 12,754 | 7,158 | 5,548 | 4,561 | 3,868 | 2,991 |
| Gross pool (ac-ft) | 56,220 | Percent gross pool | 89% | 95% | 105% | 108% | 110% | 111% | 113% |
| | | Volume of spill (ac-ft) | 0 | 0 | 9,177 | 18,608 | 28,601 | 38,877 | 52,489 |
| | | **Combined space available** | **255,000** | **202,000** | **167,000** | **144,000** | **123,000** | **109,000** | **93,000** |

Note:
1. The acronym "TIS" refers to "top of induced surcharge". Space Available is equal to Storage at Proposed TIS less Peak Storage.

# TABLE VII-5 (CONT.)

# AVAILABLE STORAGE WITHIN HEADWATER RESERVOIRS

| Yuba and Bear Rivers | | | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
|---|---|---|---|---|---|---|---|---|---|
| ***Jackson Meadows*** | | Peak outflow (cfs) | 35 | 35 | 35 | 131 | 636 | 1,677 | 3,523 |
| | | Peak storage (ac-ft) | 40,718 | 48,779 | 51,946 | 54,531 | 56,076 | 57,066 | 58,593 |
| Storage at proposed TIS (ac-ft) | 75,980 | Space available (ac-ft) | 35,262 | 27,201 | 24,034 | 21,449 | 19,904 | 18,914 | 17,387 |
| Gross pool (ac-ft) | 54,123 | Percent gross pool | 75% | 90% | 96% | 101% | 104% | 105% | 108% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 522 | 3,494 | 6,712 | 12,351 |
| ***Bowman*** | | Peak outflow (cfs) | 254 | 254 | 254 | 299 | 304 | 345 | 375 |
| | | Peak storage (ac-ft) | 39,980 | 41,442 | 44,993 | 47,980 | 51,426 | 55,349 | 61,101 |
| Storage at proposed TIS (ac-ft) | 68,884 | Space available (ac-ft) | 28,904 | 27,442 | 23,891 | 20,904 | 17,458 | 13,535 | 7,783 |
| Gross pool (ac-ft) | 60,150 | Percent gross pool | 66% | 69% | 75% | 80% | 85% | 92% | 102% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Fordyce*** | | Peak outflow (cfs) | 5 | 5 | 5 | 5 | 5 | 939 | 3,057 |
| *Note: flash restricted* | | Peak storage (ac-ft) | 20,475 | 28,548 | 31,424 | 34,296 | 37,311 | 39,242 | 39,957 |
| Storage at proposed TIS (ac-ft) | 47,659 | Space available (ac-ft) | 27,184 | 19,111 | 16,235 | 13,363 | 10,348 | 8,417 | 7,702 |
| Gross pool (ac-ft) | 39,071 | Percent gross pool | 52% | 73% | 80% | 88% | 95% | 100% | 102% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 1,532 | 7,171 |
| ***Spaulding*** | | Peak outflow (cfs) | 601 | 5,904 | 11,055 | 15,147 | 19,181 | 23,504 | 29,854 |
| *Note: flash restricted* | | Peak storage (ac-ft) | 42,471 | 66,393 | 68,505 | 69,440 | 70,370 | 71,357 | 72,316 |
| Storage at proposed TIS (ac-ft) | 72,706 | Space available (ac-ft) | 30,235 | 6,313 | 4,201 | 3,266 | 2,336 | 1,349 | 390 |
| Gross pool (ac-ft) | 61,542 | Percent gross pool | 69% | 108% | 111% | 113% | 114% | 116% | 118% |
| | | Volume of spill (ac-ft) | 0 | 22,801 | 39,675 | 53,876 | 69,044 | 87,683 | 122,619 |
| ***Scotts Flat*** | | Peak outflow (cfs) | 611 | 1,260 | 1,862 | 2,232 | 2,584 | 2,986 | 3,475 |
| | | Peak storage (ac-ft) | 48,892 | 49,226 | 49,538 | 49,729 | 49,910 | 50,070 | 50,226 |
| Storage at proposed TIS (ac-ft) | 53,413 | Space available (ac-ft) | 4,521 | 4,187 | 3,875 | 3,684 | 3,503 | 3,343 | 3,187 |
| Gross pool (ac-ft) | 48,402 | Percent gross pool | 101% | 102% | 102% | 103% | 103% | 103% | 104% |
| | | Volume of spill (ac-ft) | 2,204 | 10,040 | 17,476 | 22,095 | 26,360 | 30,448 | 35,435 |
| ***Merle Collins*** | | Peak outflow (cfs) | 1,698 | 3,703 | 5,479 | 6,569 | 7,605 | 8,587 | 9,801 |
| | | Peak storage (ac-ft) | 58,024 | 58,948 | 59,551 | 59,921 | 60,273 | 60,606 | 61,018 |
| Storage at proposed TIS (ac-ft) | 67,200 | Space available (ac-ft) | 9,176 | 8,252 | 7,649 | 7,279 | 6,927 | 6,594 | 6,182 |
| Gross pool (ac-ft) | 57,000 | Percent gross pool | 102% | 103% | 104% | 105% | 106% | 106% | 107% |
| | | Volume of spill (ac-ft) | 12,606 | 34,533 | 55,479 | 68,542 | 80,602 | 92,157 | 106,258 |
| ***Rollins*** | | Peak outflow (cfs) | 4,651 | 11,317 | 14,730 | 17,160 | 19,425 | 21,454 | 24,133 |
| | | Peak storage (ac-ft) | 67,994 | 69,654 | 70,285 | 70,735 | 71,173 | 71,675 | 72,333 |
| Storage at proposed TIS (ac-ft) | 77,438 | Space available (ac-ft) | 9,444 | 7,784 | 7,153 | 6,703 | 6,265 | 5,763 | 5,105 |
| Gross pool (ac-ft) | 65,998 | Percent gross pool | 103% | 106% | 106% | 107% | 108% | 109% | 110% |
| | | Volume of spill (ac-ft) | 24,012 | 77,799 | 101,133 | 116,335 | 129,827 | 141,614 | 154,910 |
| ***Camp Far West*** | | Peak outflow (cfs) | 9,466 | 27,226 | 36,193 | 42,649 | 48,646 | 54,185 | 61,136 |
| | | Peak storage (ac-ft) | 112,285 | 122,525 | 127,150 | 130,116 | 132,869 | 135,415 | 138,607 |
| Storage at proposed TIS (ac-ft) | 145,560 | Space available (ac-ft) | 33,275 | 23,035 | 18,410 | 15,444 | 12,691 | 10,145 | 6,953 |
| Gross pool (ac-ft) | 102,000 | Percent gross pool | 110% | 120% | 125% | 128% | 130% | 133% | 136% |
| | | Volume of spill (ac-ft) | 127,400 | 273,278 | 336,523 | 377,768 | 414,389 | 446,391 | 482,529 |
| | | **Combined space available** | **43,000** | **31,000** | **26,000** | **22,000** | **19,000** | **16,000** | **12,000** |

Note:

1. The acronym "TIS" refers to "top of induced surcharge". Space Available is equal to Storage at Proposed TIS less Peak Storage.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE VII-5 (CONT.)

# AVAILABLE STORAGE WITHIN HEADWATER RESERVOIRS

| **American River** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
|---|---|---|---|---|---|---|---|---|---|
| ***French Meadows*** | | Peak outflow (cfs) | 408 | 408 | 408 | 408 | 1,235 | 3,476 | 7,908 |
| | | Peak storage (ac-ft) | 67,072 | 83,509 | 97,918 | 109,357 | 115,312 | 120,757 | 127,653 |
| Storage at proposed TIS (ac-ft) | 146,799 | Space available (ac-ft) | 79,727 | 63,290 | 48,881 | 37,442 | 31,487 | 26,042 | 19,146 |
| Gross pool (ac-ft) | 111,300 | Percent gross pool | 60% | 75% | 88% | 98% | 104% | 108% | 115% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 8,334 | 20,295 | 36,677 |
| ***Hell Hole*** | | Peak outflow (cfs) | 1,010 | 1,010 | 1,010 | 1,010 | 1,010 | 4,054 | 16,763 |
| | | Peak storage (ac-ft) | 130,856 | 149,687 | 168,240 | 183,479 | 199,182 | 205,273 | 208,290 |
| Storage at proposed TIS (ac-ft) | 221,952 | Space available (ac-ft) | 91,096 | 72,265 | 53,712 | 38,473 | 22,770 | 16,679 | 13,662 |
| Gross pool (ac-ft) | 204,000 | Percent gross pool | 64% | 73% | 82% | 90% | 98% | 101% | 102% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 11,209 | 33,007 |
| ***Loon Lake*** | | Peak outflow (cfs) | 158 | 158 | 158 | 158 | 158 | 158 | 158 |
| | | Peak storage (ac-ft) | 41,089 | 45,537 | 50,121 | 53,930 | 57,856 | 61,875 | 67,325 |
| Storage at proposed TIS (ac-ft) | 83,275 | Space available (ac-ft) | 42,186 | 37,738 | 33,154 | 29,345 | 25,419 | 21,400 | 15,950 |
| Gross pool (ac-ft) | 76,168 | Percent gross pool | 54% | 60% | 66% | 71% | 76% | 81% | 88% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Union Valley*** | | Peak outflow (cfs) | 1,000 | 2,125 | 5,760 | 8,999 | 12,499 | 15,954 | 21,533 |
| | | Peak storage (ac-ft) | 209,976 | 240,813 | 251,947 | 259,286 | 266,166 | 272,731 | 281,735 |
| Storage at proposed TIS (ac-ft) | 292,772 | Space available (ac-ft) | 82,796 | 51,959 | 40,825 | 33,486 | 26,606 | 20,041 | 11,037 |
| Gross pool (ac-ft) | 234,989 | Percent gross pool | 89% | 102% | 107% | 110% | 113% | 116% | 120% |
| | | Volume of spill (ac-ft) | 0 | 15,732 | 39,130 | 57,835 | 77,469 | 97,473 | 124,752 |
| ***Ice House*** | | Peak outflow (cfs) | 288 | 288 | 288 | 288 | 288 | 1,027 | 3,179 |
| | | Peak storage (ac-ft) | 25,378 | 25,380 | 28,707 | 32,074 | 35,794 | 38,328 | 40,102 |
| Storage at proposed TIS (ac-ft) | 46,725 | Space available (ac-ft) | 21,347 | 21,345 | 18,018 | 14,651 | 10,931 | 8,397 | 6,623 |
| Gross pool (ac-ft) | 37,121 | Percent gross pool | 68% | 68% | 77% | 86% | 96% | 103% | 108% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 2,443 | 7,891 |
| | | **Combined space available** | **317,000** | **247,000** | **195,000** | **153,000** | **117,000** | **93,000** | **66,000** |
| **Cosumnes above Michigan Bar** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***Sly Park Reservoir*** | | Peak outflow (cfs) | 250 | 2,872 | 4,092 | 5,088 | 6,135 | 6,807 | 7,055 |
| | | Peak storage (ac-ft) | 41,224 | 42,886 | 43,423 | 43,825 | 44,200 | 44,653 | 45,904 |
| Storage at proposed TIS (ac-ft) | 46,339 | Space available (ac-ft) | 5,115 | 3,453 | 2,916 | 2,514 | 2,139 | 1,686 | 435 |
| Gross pool (ac-ft) | 41,033 | Percent gross pool | 100% | 105% | 106% | 107% | 108% | 109% | 112% |
| | | Volume of spill (ac-ft) | 1,391 | 17,064 | 26,052 | 32,900 | 39,802 | 46,705 | 55,802 |
| | | **Combined space available** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Mokelumne above Pardee** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***Salt Springs*** | | Peak outflow (cfs) | 463 | 600 | 600 | 1,686 | 6,922 | 23,858 | 39,107 |
| | | Peak storage (ac-ft) | 41,159 | 80,451 | 110,815 | 133,960 | 136,163 | 139,655 | 141,991 |
| Storage at proposed TIS (ac-ft) | 147,441 | Space available (ac-ft) | 106,282 | 66,990 | 36,626 | 13,481 | 11,278 | 7,786 | 5,450 |
| Gross pool (ac-ft) | 133,498 | Percent gross pool | 31% | 60% | 83% | 100% | 102% | 105% | 106% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 3,236 | 31,946 | 63,262 | 115,422 |

Note:

1. The acronym "TIS" refers to "top of induced surcharge". Space Available is equal to Storage at Proposed TIS less Peak Storage.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE VII-5 (CONT.)

## AVAILABLE STORAGE WITHIN HEADWATER RESERVOIRS

| Mokelumne above Pardee (Continued) | | | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
|---|---|---|---|---|---|---|---|---|---|
| ***Lower Bear*** | | Peak outflow (cfs) | 220 | 220 | 220 | 220 | 220 | 220 | 1,419 |
| | | Peak storage (ac-ft) | 19,984 | 21,708 | 27,272 | 32,093 | 37,219 | 42,882 | 48,083 |
| Storage at proposed TIS (ac-ft) | 52,862 | Space available (ac-ft) | 32,878 | 31,154 | 25,590 | 20,769 | 15,643 | 9,980 | 4,779 |
| Gross pool (ac-ft) | 42,936 | Percent gross pool | 47% | 51% | 64% | 75% | 87% | 100% | 112% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 7,535 |
| | | **Combined space available** | **139,000** | **98,000** | **62,000** | **34,000** | **27,000** | **18,000** | **10,000** |
| **Stanislaus above New Melones** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***New Spicer Meadows*** | | Peak outflow (cfs) | 17 | 17 | 350 | 350 | 350 | 350 | 350 |
| | | Peak storage (ac-ft) | 84,950 | 96,300 | 100,631 | 104,186 | 111,193 | 119,157 | 131,635 |
| Storage at proposed TIS (ac-ft) | 210,500 | Space available (ac-ft) | 125,550 | 114,200 | 109,869 | 106,314 | 99,307 | 91,343 | 78,865 |
| Gross pool (ac-ft) | 189,000 | Percent gross pool | 45% | 51% | 53% | 55% | 59% | 63% | 70% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Donnells*** | | Peak outflow (cfs) | 766 | 766 | 766 | 4,720 | 14,010 | 23,464 | 35,384 |
| | | Peak storage (ac-ft) | 19,944 | 29,562 | 48,927 | 58,262 | 59,991 | 61,470 | 62,765 |
| Storage at proposed TIS (ac-ft) | 63,488 | Space available (ac-ft) | 43,544 | 33,926 | 14,561 | 5,226 | 3,497 | 2,018 | 723 |
| Gross pool (ac-ft) | 56,893 | Percent gross pool | 35% | 52% | 86% | 102% | 105% | 108% | 110% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 9,327 | 29,746 | 52,552 | 88,335 |
| ***Beardsley*** | | Peak outflow (cfs) | 650 | 2,569 | 7,811 | 11,368 | 23,202 | 39,758 | 58,414 |
| | | Peak storage (ac-ft) | 58,061 | 79,352 | 81,698 | 82,847 | 85,875 | 89,459 | 92,968 |
| Storage at proposed TIS (ac-ft) | 101,400 | Space available (ac-ft) | 43,339 | 22,048 | 19,702 | 18,553 | 15,525 | 11,941 | 8,432 |
| Gross pool (ac-ft) | 77,838 | Percent gross pool | 75% | 102% | 105% | 106% | 110% | 115% | 119% |
| | | Volume of spill (ac-ft) | 0 | 16,546 | 33,926 | 57,576 | 93,780 | 133,759 | 194,576 |
| | | **Combined space available** | **212,000** | **170,000** | **144,000** | **130,000** | **118,000** | **105,000** | **88,000** |
| **Tuolumne above Don Pedro** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***Hetch Hetchy*** | | Peak outflow (cfs) | 1,500 | 6,451 | 8,612 | 15,087 | 22,228 | 32,428 | 49,142 |
| | | Peak storage (ac-ft) | 287,298 | 313,245 | 330,028 | 338,689 | 349,718 | 357,113 | 366,705 |
| Storage at proposed TIS (ac-ft) | 366,295 | Space available (ac-ft) | 78,997 | 53,050 | 36,267 | 27,606 | 16,577 | 9,182 | -410 |
| Gross pool (ac-ft) | 341,000 | Percent gross pool | 84% | 92% | 97% | 99% | 103% | 105% | 108% |
| | | Volume of spill (ac-ft) | 0 | 0 | 1,625 | 21,695 | 44,718 | 72,343 | 115,852 |
| ***Lake Eleanor*** | | Peak outflow (cfs) | 505 | 3,488 | 8,707 | 12,171 | 15,728 | 19,735 | 25,817 |
| | | Peak storage (ac-ft) | 14,961 | 25,884 | 28,225 | 29,617 | 30,902 | 32,237 | 34,092 |
| Storage at proposed TIS (ac-ft) | 24,286 | Space available (ac-ft) | 9,325 | -1,598 | -3,939 | -5,331 | -6,616 | -7,951 | -9,806 |
| Gross pool (ac-ft) | 23,355 | Percent gross pool | 64% | 111% | 121% | 127% | 132% | 138% | 146% |
| | | Volume of spill (ac-ft) | 0 | 9,713 | 25,308 | 37,378 | 49,445 | 61,481 | 77,594 |
| ***Cherry Valley*** | | Peak outflow (cfs) | 800 | 800 | 2,166 | 2,887 | 5,030 | 8,174 | 18,178 |
| | | Peak storage (ac-ft) | 190,086 | 232,243 | 252,876 | 254,100 | 261,648 | 271,011 | 277,255 |
| Storage at proposed TIS (ac-ft) | 289,840 | Space available (ac-ft) | 99,754 | 57,597 | 36,964 | 35,740 | 28,192 | 18,829 | 12,585 |
| Gross pool (ac-ft) | 268,200 | Percent gross pool | 71% | 87% | 94% | 95% | 98% | 101% | 103% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 2,911 | 23,459 |
| | | **Combined space available** | **188,000** | **111,000** | **73,000** | **63,000** | **45,000** | **28,000** | **13,000** |

Note:
1. The acronym "TIS" refers to "top of induced surcharge". Space Available is equal to Storage at Proposed TIS less Peak Storage.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# TABLE VII-5 (CONT.)

# AVAILABLE STORAGE WITHIN HEADWATER RESERVOIRS

| San Joaquin above Friant | | | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
|---|---|---|---|---|---|---|---|---|---|
| ***Florence*** | | Peak outflow (cfs) | 15 | 15 | 15 | 15 | 15 | 1,447 | 3,000 |
| *Note: gates in operation* | | Peak storage (ac-ft) | 9,563 | 25,385 | 36,089 | 45,169 | 55,167 | 60,000 | 62,715 |
| Storage at proposed TIS (ac-ft) | 62,970 | Space available (ac-ft) | 53,407 | 37,585 | 26,881 | 17,801 | 7,803 | 2,970 | 255 |
| Gross pool (ac-ft) | 64,400 | Percent gross pool | 15% | 39% | 56% | 70% | 86% | 93% | 97% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 6,165 | 22,328 |
| ***Edison*** | | Peak outflow (cfs) | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| | | Peak storage (ac-ft) | 73,492 | 80,273 | 84,860 | 88,751 | 93,035 | 97,748 | 104,676 |
| Storage at proposed TIS (ac-ft) | 134,000 | Space available (ac-ft) | 60,508 | 53,727 | 49,140 | 45,249 | 40,965 | 36,252 | 29,324 |
| Gross pool (ac-ft) | 125,000 | Percent gross pool | 59% | 64% | 68% | 71% | 74% | 78% | 84% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Mammoth Pool*** | | Peak outflow (cfs) | 1,632 | 2,430 | 2,430 | 12,605 | 33,829 | 51,585 | 70,880 |
| | | Peak storage (ac-ft) | 23,869 | 63,244 | 105,874 | 126,399 | 130,087 | 133,186 | 137,334 |
| Storage at proposed TIS (ac-ft) | 146,800 | Space available (ac-ft) | 122,931 | 83,556 | 40,926 | 20,401 | 16,713 | 13,614 | 9,466 |
| Gross pool (ac-ft) | 123,000 | Percent gross pool | 19% | 51% | 86% | 103% | 106% | 108% | 112% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 25,031 | 75,410 | 140,291 | 246,746 |
| ***Huntington*** | | Peak outflow (cfs) | 500 | 500 | 500 | 500 | 500 | 500 | 1,017 |
| | | Peak storage (ac-ft) | 49,959 | 49,959 | 51,195 | 56,710 | 63,019 | 70,493 | 82,100 |
| Storage at proposed TIS (ac-ft) | 89,870 | Space available (ac-ft) | 39,911 | 39,911 | 38,675 | 33,160 | 26,851 | 19,377 | 7,770 |
| Gross pool (ac-ft) | 82,100 | Percent gross pool | 61% | 61% | 62% | 69% | 77% | 86% | 100% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 285 |
| ***Shaver*** | | Peak outflow (cfs) | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | | Peak storage (ac-ft) | 90,619 | 95,142 | 99,672 | 103,535 | 107,801 | 112,505 | 119,541 |
| Storage at proposed TIS (ac-ft) | 130,874 | Space available (ac-ft) | 40,255 | 35,732 | 31,202 | 27,339 | 23,073 | 18,369 | 11,333 |
| Gross pool (ac-ft) | 135,300 | Percent gross pool | 67% | 70% | 74% | 77% | 80% | 83% | 88% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Redinger*** | | Peak outflow (cfs) | 3,620 | 9,186 | 16,478 | 21,406 | 48,732 | 74,137 | 101,612 |
| | | Peak storage (ac-ft) | 20,056 | 25,000 | 25,000 | 25,000 | 26,272 | 27,000 | 27,797 |
| Storage at proposed TIS (ac-ft) | 36,170 | Space available (ac-ft) | 16,114 | 11,170 | 11,170 | 11,170 | 9,898 | 9,170 | 8,373 |
| Gross pool (ac-ft) | 25,000 | Percent gross pool | 80% | 100% | 100% | 100% | 105% | 108% | 111% |
| | | Volume of spill (ac-ft) | 0 | 15,990 | 36,756 | 83,122 | 157,179 | 247,131 | 392,278 |
| ***Bass Lake*** | | Peak outflow (cfs) | 140 | 140 | 140 | 445 | 1,226 | 2,383 | 4,293 |
| | | Peak storage (ac-ft) | 25,451 | 28,781 | 32,693 | 34,711 | 36,233 | 37,244 | 38,882 |
| Storage at proposed TIS (ac-ft) | 46,252 | Space available (ac-ft) | 20,801 | 17,471 | 13,559 | 11,541 | 10,019 | 9,008 | 7,370 |
| Gross pool (ac-ft) | 34,200 | Percent gross pool | 74% | 84% | 96% | 101% | 106% | 109% | 114% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 2,258 | 6,487 | 11,263 | 18,519 |
| | | **Combined space available** | **354,000** | **279,000** | **212,000** | **167,000** | **135,000** | **109,000** | **74,000** |
| **Kings River above Pine Flat** | | | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| ***Courtright and Wishon*** | | Peak outflow (cfs) | 850 | 850 | 850 | 850 | 850 | 850 | 850 |
| *Note: Results are sum of both reservoirs.* | | Peak storage (ac-ft) | 99,930 | 99,930 | 99,930 | 106,536 | 116,827 | 129,011 | 147,213 |
| Storage at proposed TIS (ac-ft) | 248,814 | Space available (ac-ft) | 148,884 | 148,884 | 148,884 | 142,278 | 131,987 | 119,803 | 101,601 |
| Gross pool (ac-ft) | 240,936 | Percent gross pool | 41% | 41% | 41% | 44% | 48% | 54% | 61% |
| | | Volume of spill (ac-ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | **Combined space available** | **149,000** | **149,000** | **149,000** | **142,000** | **132,000** | **120,000** | **102,000** |

Note:

1. The acronym "TIS" refers to "top of induced surcharge". Space Available is equal to Storage at Proposed TIS less Peak Storage.

*Note: Prior to use and application, reference the "Expectations of Use" preface.*

# CHAPTER VIII

# ON-STREAM AND OFF-STREAM STORAGE

## OVERVIEW

This pilot study investigates the potential for flood damage reduction within the Sacramento and San Joaquin River Basins associated with raising existing dams or constructing new on-stream or off-stream storage projects. For the purposes of this study, off-stream storage projects are defined as projects that propose to provide significant storage capacity at a location that is physically separated from major rivers. A substantial number of these three types of projects are being considered by various agencies and organizations in the Sacramento and San Joaquin River Basins, with a focus on increasing or improving water supply. This pilot study is intended to investigate the potential that these projects may also have for flood damage reduction as a component of the Sacramento and San Joaquin River Basins Comprehensive Study.

Raising existing reservoir storage levels and constructing new on-stream storage facilities provides the opportunity to consider allocating or re-allocating dedicated flood storage space or changing operational criteria to meet flood damage reduction objectives.

Off-stream reservoirs are typically very large with respect to their tributary basins. As a result, they provide significant flood reduction for minor streams on which they are located. In addition, they may provide a location for transfer of existing on-stream reservoir conservation storage that allows re-allocation of reservoir space to increase flood control pools. Flood damage reduction benefits may be realized from off-stream storage flow transfers either prior to a flood event, by increasing available flood space, or during an event, by making diversions downstream of the reservoir that reduces peak flows in the river.

This investigation included a review of 67 potential on-stream and off-stream water storage sites within the Sacramento and San Joaquin River Basins. The potential sites were identified from recent studies conducted by CALFED (CALFED, 2000). Through use of a screening process, two pilot scenarios were selected. These scenarios are intended to investigate the potential for flood damage reduction associated with new storage projects in the two river basins. The scenarios and analyses described herein are preliminary and focus on the potential benefits of dam raises, on-stream storage projects, and off-stream storage projects at a conceptual level.

The analysis involved modifications to existing HEC-5 hydrologic models for the basin and comparison of these results to data previously generated by the Water Management Section of the U.S. Army Corps of Engineers (USACE) for existing (baseline) conditions.

## PROJECT SELECTION

Two conceptual project scenarios were identified for flood damage reduction analysis through review of existing documentation. The scenarios were selected using the following steps.

### Step 1 - Potential Storage Project Identification

Within the Sacramento and San Joaquin River Basins, a total of 67 potential reservoir projects were compiled from the following two documents:

- **Initial Surface Water Storage Screening**, Integrated Storage Investigation, CALFED Bay-Delta Program, August 2000.
- **Technical Memorandum 4, Draft Long List of Alternatives**, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River, Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, Nov 22, 2000.

These documents investigated potential reservoir projects with respect to water supply objectives. As a result, the list does not represent all potential reservoir sites that might provide flood damage reduction in the basins. The initial list of the potential projects is provided in Table VIII-1. After compilation, the list was reviewed. No additional projects were identified for consideration. A map showing the location of each project, indexed to the project numbers shown in Table VIII-1, is provided in Plate 7.

### Step 2 - Initial Screening of Projects

Thirty-nine of the projects were recommended to be eliminated from further consideration in this study based on storage size, diversion location, and results of previous studies. All projects that impounded less than 200,000 acre-feet were also eliminated. This value was set as the lower limit for projects that might provide significant regional flood damage reduction benefits. All projects having a point of diversion from the Sacramento and San Joaquin River Delta were also eliminated. Flood damage reduction benefits associated with these projects would be limited to the downstream portion of the basins, and would not address significant flooding problems identified in the remainder of the study area. The Trinity Lake Enlargement project was eliminated because it is located outside of the drainage basin.

Projects upstream of Shasta Reservoir were eliminated because Shasta presently has the capacity to control peak outflows at or below the objective flow up to the flows corresponding to the annual 1-percent chance exceedence event. In addition, several projects were identified that had been extensively studied in the past and did not appear likely to be constructed. These projects were subsequently eliminated from the list. The list of projects recommended for elimination from further consideration in this study is shown in Table VIII-1.

# TABLE VIII-1

## COMPOSITE LIST OF POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Storage Type | Storage Size | Description | Documentation* | Reason For Preliminary Elimination |
|---|---|---|---|---|---|---|
| Allen Camp Reservoir | 29 | On-Stream | 196,000 | Not Provided | CALFED NO. 1 | 200,000 ac-ft or Smaller |
| Arroyo Pasajero | 66 | On-Stream | 52,000 | Construction of 17,000 ac-ft reservoir on Los Gatos Creek and 35,000 ac-ft reservoir on Warthan Creek. | URS NO. S17 | 200,000 ac-ft or Smaller |
| Auburn Reservoir | 1 | On-Stream | 2,300,000 | Construct a new dam on the North Fork of the American River near Auburn and store instream flows. | CALFED NO. 2 | Previous Extensive Study |
| Bella Vista | 2 | On-Stream | 146,000 | Not Provided | CALFED NO. 3 | 200,000 ac-ft or Smaller |
| Big Dry Creek Dam | 56 | Off-Stream | varies, but <13,500 | Utilize excess storage space in the existing Big Dry Creek Reservoir in the spring and summer months. Flows Diverted from the Friant Kern Canal. | URS NO. S5 | 200,000 ac-ft or Smaller |
| Chain of Lakes Facility | 15 | Island Storage | 300,000 to 600,000 | Conversion of six major Delta Islands to reservoirs connected with siphons and pumps and Diverting water from the Delta. | CALFED NO. 5 | Source of Diversion |
| Clay Station | 42 | Off-Stream | 170,000 | The reservoir would be located on Luguna Creek in Sacramento County with Flows diverted from the American River. | CALFED NO. 7 | 200,000 ac-ft or Smaller |
| Coloma Reservoir | 3 | On-Stream | 710,000 | Reservoir would be located on the South Fork of the American River near Coloma and store instream flows. | CALFED NO. 8 | Retained For Further Consideration |
| Colusa Reservoir Complex | 18 | Off-Stream | 3,300,000 | Extension of the proposed Sites Reservoir. Includes two additional large dams where Hunter and Logan Creeks pass through Logan Ridge, and several saddle dams. Flows would be diverted from the Sacramento River. | CALFED NO. 9 | Retained For Further Consideration |
| Cooperstown Reservoir | 43 | Off-Stream | 609,000 | The reservoir would be located on Dry Creek between Stanislaus an Tuolumne Rivers Flows would be diverted from New Melones and Don Pedro reservoirs | CALFED NO. 10 | Retained For Further Consideration |
| Cottonwood Creek Reservoir Complex | 19 | Off-Stream and On-Stream | 1,600,000 | Construction of two reservoirs 900,000 ac-ft on the main stream of Cottonwood Creek and 700,000 ac-ft on the South Fork of Cottonwood Creek. | CALFED NO. 11 | Previous Extensive Study |
| Dear Creek Meadows | 4 | On-Stream | 200,000 | Reservoir would be located on Deer Creek in Tehama County. | CALFED NO. 12 | 200,000 ac-ft or Smaller |
| Deer Creek Reservoir | 44 | Off-Stream | 600,000 | The reservoir would be located on Deer Creek in Sacramento County. Flow would be diverted from the American River. | CALFED NO. 13 | Retained For Further Consideration |
| Dinkey Creek Dam | 60 | On-Stream | 200,000 | Construction of a new dam on Dinkey Creek, a tributary to the North Fork of the Kings River. | URS NO. S9 | 200,000 ac-ft or Smaller |

**** Documentation Refers to:***
***Initial Surface Water Storage Screening**, Integrated Storage Investigation, CALFED Bay-Delta Program,* August 2000.
***Technical Memorandum 4, Draft Long List of Alternatives**, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River, Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, Nov 22, 2000.*

# TABLE VIII-1 (CONT.)

## COMPOSITE LIST OF POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Storage Type | Storage Size | Description | Documentation* | Reason For Preliminary Elimination |
|---|---|---|---|---|---|---|
| Dry Creek Dam | 63 | Off-Stream | 444,000 | Construction of a new dam on Dry Creek about 7 miles southwest of Terminus Dam. Flow would be diverted from the Kaweah River. | URS NO. S12 | Retained For Further Consideration |
| Duck Creek | 45 | Off-Stream | 100,000 | The reservoir would be located in the Calaveras watershed in San Joaquin County. Flow would be diverted from the Mokelumne and Calaveras Rivers | CALFED NO. 15 | 200,000 ac-ft or Smaller |
| Farmington Reservoir Enlargement | 46 | Off-Stream and On-Stream | 100,000 | Enlargement of the Farmington Reservoir | CALFED NO. 16 | 200,000 ac-ft or Smaller |
| Fiddlers Reservoir | 20 | Off-Stream and On-Stream | 310,000 to 545,000 | Construction of a new dam on the Middle Fork of Cottonwood Creek. Flow would be diverted from the Middle fork of Cottonwood Creek | CALFED NO. 17 | Previous Extensive Study |
| Fine Gold Creek Dam | 55 | Off-Stream | 350,000 | Construction of a dam upstream of the confluence of Fine Gold Creek and Millerton Lake. Flow would be diverted from Millerton Lake. | URS NO. S4 | Retained For Further Consideration |
| Folsom Reservoir | 5 | On-Stream | 365,000 | Enlargement of Folsom Reservoir by increasing the height of Folsom Dam by 30 feet | CALFED NO. 18 | Retained For Further Consideration |
| Freemans Crossing Reservoir | 6 | On-Stream | 300,000 | A dam would be constructed near Freemans Crossing on the Middle Fork of the Yuba River and divert water from the North Fork. | CALFED NO. 19 | Retained For Further Consideration |
| Galatin Reservoir | 21 | On-Stream | 183,000 | Not Provided | CALFED NO. 20 | 200,000 ac-ft or Smaller |
| Garden Bar Reservoir | 7 | On-Stream | 245,000 | Construction of a 320 foot high dam on the Bear River upstream of Camp Far West Reservoir. | CALFED NO. 21 | Retained For Further Consideration |
| Garzas Reservoir | 30 | Off-Stream | 139,000 to 1,754,000 | The reservoir would be located on Ganzas Creek in Stanislaus County | CALFED NO. 22 | Retained For Further Consideration |
| Glenn Reservoir Project | 22 | Off-Stream | 8,206,000 | Construction of Rancheria Dam on the main stream of Stony Creek and Newville Dam on the North Fork of Stony Creek. One of the Dams would be 420 feet tall. Would store runoff from Stony and Thomes Creeks and pumped flows from the Sacramento River. | CALFED NO. 23 | Retained For Further Consideration |
| Ground Water Conjunctive Use | 52 | Off-Stream | 500,000 to 1,000,000 | Groundwater Storage in Sacramento Valley, San Joaquin Valley, and Southern California | CALFED | Source of Diversion |

**** Documentation Refers to:***
***Initial Surface Water Storage Screening****, Integrated Storage Investigation, CALFED Bay-Delta Program,* August 2000.
***Technical Memorandum 4, Draft Long List of Alternatives****, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River, Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, Nov 22,000.*

# TABLE VIII-1 (CONT.)

# COMPOSITE LIST OF POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Storage Type | Storage Size | Description | Documentation* | Reason For Preliminary Elimination |
|---|---|---|---|---|---|---|
| Hulen Reservoir | 23 | On-Stream | 96,000 to | Construction of a Dam on the North Fork of Cottonwood Creek. | CALFED NO. 24 | Previous Extensive Study |
| Hungry Hollow Reservoir | 65 | Off-Stream and On-Stream | 800,000 | Construction of a 260 foot high dam on Deer Creek. Would store in-stream flows and diversions from Lake Success. | URS NO. S14 | Retained For Further Consideration |
| In-Delta Storage | 16 | Island Storage | 230,000 | Conversion of several south delta islands to reservoirs. Water would be diverted from the Sacramento or San Joaquin Rivers during high flows and released during lower flows. | CALFED NO. 14 | Source of Diversion |
| Ingram Canyon | 31 | Off-Stream | 333,000 to 1,201,000 | The reservoir would be located on Ingram Creek in Stanislaus County. Flows would be diverted from the California Aqueduct. | CALFED NO. 25 | Source of Diversion |
| Kettleman Plain | 32 | Off-Stream | 133,000 to 283,000 | The reservoir would be located in Kings County west of the California Aqueduct. Flows would be diverted from the California Aqueduct. | CALFED NO. 26 | Source of Diversion |
| Kosk Reservoir | 8 | On-Stream | 800,000 | Construction of a reservoir on the Pit River approximately two miles downstream of Big Bend. | CALFED NO. 27 | Significant Existing Storage |
| Lake Beryessa Enlargement | 24 | Off-Stream and On-Stream | 4,400,000 to | Construction of a new dam 2 miles downstream of the existing Montecello Dam. Flows would be diverted from the Sacramento River. | CALFED NO. 4 | Retained For Further Consideration |
| Little Salado-Crow Reservoir | 33 | Off-Stream | 132,000 to 250,000 | The Reservoir would be located Crow Creek in Stanislaus County. Flows would be diverted from the California Aqueduct. | CALFED NO. 28 | Source of Diversion |
| Los Banos Grandes | 34 | Off-Stream | 275,000 to 2,030,000 | The reservoir would be located on Los Banos Creek in Merced County. Flows would be diverted from the California Aqueduct. | CALFED NO. 29<br>URS NO. S15 | Source of Diversion |
| Los Vaqueros Enlargement | 35 | Off-Stream | 965,000 | Increase the size of the existing Los Vaqueros Reservoir located on Kellogg Creek in Contra Costa County. Flows would be diverted from the California Aqueduct. | CALFED NO. 30 | Source of Diversion |
| Mammoth Pool Expansion | 54 | On-Stream | 35,000 | Installation of spillway gates to raise the normal operating pool and increase the active storage. | URS NO. S3 | 200,000 ac-ft or Smaller |
| Marysville Reservoir | 9 | On-Stream | 916,000 | The reservoir would be located on the mainstem of the Yuba River downstream of Englebright Reservoir | CALFED NO. 31 | Previous Extensive Study |

**** Documentation Refers to:***
***Initial Surface Water Storage Screening****, Integrated Storage Investigation, CALFED Bay-Delta Program,* August 2000.
***Technical Memorandum 4, Draft Long List of Alternatives****, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River, Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, Nov 22, 2000.*

# TABLE VIII-1 (CONT.)

## COMPOSITE LIST OF POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Storage Type | Storage Size | Description | Documentation* | Reason For Preliminary Elimination |
|---|---|---|---|---|---|---|
| Mill Creek Dam | 59 | Off-Stream | 1,000,000 | Construction of a new dam on Mill Creek 1.3 miles upstream from the confluence of Mill Creek and the Kings River. Flow would be diverted from Pine Flat Reservoir | URS NO. S8 | Retained For Further Consideration |
| Millerton Lake Enlargement | 47 | On-Stream | 720,000 | Increase the height of Friant Dam 144 feet and construct three saddle dams | CALFED NO. 32<br>URS NO. S1 | Retained For Further Consideration |
| Millville Reservoir | 10 | On-Stream | 206,000 | The reservoir would be located on south Cow Creek in Shasta County | CALFED NO. 33 | Retained For Further Consideration |
| Montgomery Reservoir | 48 | Off-Stream | 240,000 | The reservoir would be located on Dry Creek in Merced County. Flows would be diverted from Lake McClure | CALFED NO. 34 | Retained For Further Consideration |
| Nashville Reservoir | 49 | Off-Stream and On-Stream | 1,155,000 | The reservoir would be located on the Cosumnes River approximately 5 miles north of Plymouth. | CALFED NO. 35 | Retained For Further Consideration |
| Orestimba Reservoir | 36 | Off-Stream | 380,000 to 1,140,000 | The reservoir would be located on Orestimba Creek in Stanislaus County. Flow would be diverted from the California Aqueduct. | CALFED NO. 36 | Source of Diversion |
| Panoche Reservoir | 37 | Off-Stream | 160,000 to 3,100,000 | The reservoir would be located on Panoche and Silver Creeks in San Benito and Fresno Counties. Flow would be diverted from the California Aqueduct. | CALFED NO. 37<br>URS NO. S16 | Source of Diversion |
| Pardee Reservoir Enlargement | 50 | On-Stream | 150,000 | Enlargement of the Pardee Reservoir | CALFED NO. 38 | 200,000 ac-ft or Smaller |
| Quinto Creek Reservoir | 38 | Off-Stream | 332,000 to 381,000 | The reservoir would be located on Quinto Creek in Merced and Stanislaus Counties. Flow would be diverted from the California Aqueduct. | CALFED NO. 39 | Source of Diversion |
| Raise Pine Flat Dam | 57 | On-Stream | 45,000 | Raise crest of Pine Flat Dam by adding a 7-ft parapet wall | URS NO. S6 | 200,000 ac-ft or Smaller |
| Raise Terminus Dam | 61 | On-Stream | 250,000 to 1,200,000 | Raise dam crest by 106, 206 or 306 ft. It is probable that the existing dam would need to be replaced to achieve these levels of construction. | URS NO. S10 | Retained For Further Consideration |
| Red Bank Project (Dippingvat-Schoenfield | 25 | Off-Stream and On-Stream | 354,000 | Construction of 104,000 Acre-foot Dippingvat Reservoir on the Southfork of Cottonwood Creek and 250,000 Acre-foot Schoenfield Reservoir on Red Bank Creek. | CALFED NO. 40 | Previous Extensive Study |
| Rogers Crossing Dam | 58 | On-Stream | 950,000 | Construction of a dam 1/2 mile upstream of the confluence of the North Fork and the Kings River | URS NO. S7 | Retained For Further Consideration |
| Romero | 39 | Off-Stream | 184,000 | Not Provided | CALFED NO. 41 | 200,000 ac-ft or Smaller |
| San Luis Reservoir Enlargement | 40 | Off-Stream | 390,000 | Raise the height of the existing San Luis Reservoir dam by 40 feet. Flow would be diverted from the California Aqueduct. | CALFED NO. 52 | Source of Diversion |

**** Documentation Refers to:***
***Initial Surface Water Storage Screening****, Integrated Storage Investigation, CALFED Bay-Delta Program,* August 2000.
***Technical Memorandum 4, Draft Long List of Alternatives****, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River, Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, Nov 22, 2000.*

# TABLE VIII-1 (CONT.)

## COMPOSITE LIST OF POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Storage Type | Storage Size | Description | Documentation* | Reason For Preliminary Elimination |
|---|---|---|---|---|---|---|
| Shasta Lake Enlargement | 26 | On-Stream | 300,000 | Raise Shasta Dam 6 to 8 feet. | CALFED NO. 43 | Retained For Further Consideration |
| Sites Reservoir | 27 | Off-Stream | 1,200,000 to 1,900,000 | Reservoir would be formed by Golden Gate Dam on Funks Creek and Sites Dam on Stone Corral Creek. The smaller version would require the construction of 5 dikes. The | CALFED NO. 44 | Retained For Further Consideration |
| South Gulch Reservoir | 51 | Off-Stream | 180,000 | The reservoir would be located on South Gulch in San Joaquin County. Flows would be diverted from the Calaveras and Stanislaus Rivers. | CALFED NO. 45 | 200,000 ac-ft or Smaller |
| Squaw Valley Reservoir | 11 | Off-Stream and On-Stream | 400,000 | The reservoir would be located on Squaw Valley Creek, a tributary to the McCloud River. | CALFED NO. 52 | Significant Existing Storage |
| Success Dam Raise | 64 | On-Stream | 28,000 | Raise the Height of Success Dam by 10-Feet | URS NO. S13 | 200,000 ac-ft or Smaller |
| Sunflower Reservoir | 41 | Off-Stream | 360,000 to 600,000 | The reservoir would be located on Avenal Creek in Kings and Kern Counties. Flow would be diverted from the California Aqueduct. | CALFED NO. 47 | Source of Diversion |
| Temperance Flat Dam | 53 | On-Stream | 1,400,000 | Construction of a dam upstream of Friant Dam in the upstream end of Millerton Lake | URS NO. S2 | Retained For Further Consideration |
| Thomes- Newville Reservoir | 28 | Off-Stream | 1,840,000 to 3,080,000 | Reservoir would be constructed on the North Fork of Stony Creek. An afterbay would be constructed downstream. Flow would be diverted from Stony Creek, Thomes Creek and the Sacramento River. | CALFED NO. 48 | Retained For Further Consideration |
| Trinity Lake Enlargement (Formerly Clair Engle Lake) | 17 | Off-Stream and On-Stream | 4,800,000 | Increase storage capacity of Trinity Lake by raising the height of Trinity Dam by 200 feet. Flow would be diverted from Shasta Lake. | CALFED NO. 6 | Source of Diversion |
| Tulare Lake Basin | 67 | Off-Stream | 100,000 | Purchase of Storage Facilities created at the south end of the Tulare Lake Basin. Flow would be diverted from the California Aqueduct, Kings, Kaweah, and Tule Rivers | URS NO. S18 | 200,000 ac-ft or Smaller |
| Tuscan Buttes Reservoir | 12 | Off-Stream | 3,675,000 to 5,500,000 | The reservoir would be located on Paynes and Inks Creeks. Flows would be diverted from the Sacramento river. | CALFED NO. 49 | Retained For Further Consideration |

***Documentation Refers to:**
***Initial Surface Water Storage Screening**, Integrated Storage Investigation, CALFED Bay-Delta Program,* August 2000.
***Technical Memorandum 4, Draft Long List of Alternatives**, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River, Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, Nov 22, 2000.*

## TABLE VIII-1 (CONT.)

## COMPOSITE LIST OF POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Storage Type | Storage Size | Description | Documentation* | Reason For Preliminary Elimination |
|---|---|---|---|---|---|---|
| Waldo Reservoir | 13 | Off-Stream | 60,000 to 300,000 | The reservoir would be located on Dry Creek in Yuba County. Flows would be diverted from the Yuba, and Bear Rivers. | CALFED NO. 50 | Retained For Further Consideration |
| Wing Reservoir | 14 | On-Stream | 244,000 | The reservoir would be located on Inks Creek at the same location as the Tuscan Buttes Reservoir. | CALFED NO. 51 | Retained For Further Consideration |
| Yokohl Creek Dam | 62 | Off-Stream | 970,000 | Construction of a new dam on Yokohl Creek about 8 miles southwest of Terminus Dam. Flows would be diverted from the Kaweah River. | URS NO. S11 | Retained For Further Consideration |

**** Documentation Refers to:***
***Initial Surface Water Storage Screening****, Integrated Storage Investigation, CALFED Bay-Delta Program,* August 2000.
***Technical Memorandum 4, Draft Long List of Alternatives****, Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River, Friant Water Users Association and National Resource and Natural Resources Defense Council Coalition, Nov 22, 2000.*

### Step 3 - Ranking of Remaining Projects

The remaining projects were ranked based on parameters including flow excess, storage size, and basin area. Flow excess was defined as the amount by which the annual 1-percent chance exceedence flow exceeded the objective flow or channel capacity at downstream reservoir control points or model index points (the maximum flow excess was used where multiple control or index points existed). The location of selected reservoir control and model index points are provided in Plate 7, and a summary of the points are provided in Table VIII-2.

The projects were ranked based on their ratios of project storage divided by flow excess; flow excess divided by basin area; and project storage divided by basin area. For each of these ratios, larger values indicate the possibility of greater potential for flood damage reduction. The projects were sorted and ranked for each ratio, and the rankings were summed for each of the projects as an indicator of potential project performance.

### Step 4 - Short-Listed Projects

Ten projects were short-listed for potential modeling analysis, based on the ranking described above and a review of their geographic locations. The intent of the short list was to provide team a list of potential projects that appeared feasible from technical and environmental perspectives, and had the greatest likelihood of providing flood damage reduction benefits in specific geographic regions where flooding or capacity problems had previously been identified. For each major region of the study area associated with flooding problems, the ranked list of projects was reviewed, and the most promising projects of each type (raising existing dams, new on-stream, and new off-stream storage) were identified in each region. Thus, if similar projects were proposed in the same region, but one appeared to have higher potential for flood damage reduction or greater likelihood of implementation, only one project was carried forward to the short list for that particular region. It should be noted that this short-listing was only intended to narrow the choices for modeling in this study, and not to assess the feasibility of individual projects. The short list of projects is shown in Table VIII-4.

### Step 5 - Final Selection

Two scenarios were identified from the short list for modeling in this study. The selected scenarios included analysis of the regional flood damage reduction benefits of a generic off-stream storage reservoir in the Sacramento River Basin and a suite of three potential reservoir projects near Friant Dam in the San Joaquin River Basin. The Sacramento River Basin project would involve the transfer of conservation storage from Stony Gorge, East Park, Black Butte, Shasta, Oroville, and Folsom reservoirs to an off-stream site. The suite of Friant Dam projects would include raising Friant Dam, construction of Temperance Flat dam on the San Joaquin River upstream of Friant Dam, and construction Fine Gold dam on Fine Gold Creek upstream of Friant Dam.

# TABLE VIII-2

## CONTROL OR INDEX POINTS REFERENCED TO MAP LOCATION

| Reservoir Control Point or Model Index Point | Flow (cfs) | | Storm Centering | Percent Chance Exceedence Flow Exceeding Objective Flow | Map Reference Letter |
|---|---|---|---|---|---|
| | Objective | 1% Exceedence Existing | | | |
| Bend Bridge | 100,000 | 160,000 | Shasta | 2% | A |
| Ord Ferry | 130,000 | 160,000 | Black Butte | 4% | B |
| Gridley | 150,000 | 150,000 | Oroville Dam | 0.5% | C |
| Yuba City | 180,000 | 180,000 | Oroville Dam | 0.2% | |
| Marysville | 300,000 | 130,000 | Oroville Dam | None | D |
| Nicolaus | 320,000 | 325,000 | Oroville Dam | 1% (minimal), 0.5% | E |
| Marysville (Yuba R) | 180,000 | 160,000 | New Bullards Bar | 0.5% | |
| Marysville (Feather R) | 300,000 | 300,000 | New Bullards Bar | 0.5% | |
| Nicolaus (Feather) | 320,000 | 325,000 | New Bullards Bar | 2% & 1% (minimal), 0.5% | |
| Rumsey | 20,000 | 45,000 | Indian Valley | 10% | F |
| Friant Kern Canal | 7,950 | 15,000 | Pine Flat | 2% | G |
| Mendota Gage | 6,500 | 37,000 | Friant Dam | 2% | H |
| Madera Canal | 5,000 | 7,500 | Hidden | 4% or 1% | J |
| Madera Canal | 7,000 | 7,500 | Buchanan | 1% | K |
| Cressey | 6,000 | 55,000 | New Exchequer | 2% | L |
| Modesto | 9,000 | 80,000 | Don Pedro | 2% | M |
| Orange Blossom | 8,000 | 12,000 | New Melones | 2% (minimal), 1% | N |
| Los Banos | 1,000 | 1,000 | Los Banos | 0.5% | I |
| El Nido | 17,000 | 50,000 | El Nido | | O |
| Newman | 45,000 | 70,000 | Newman | | P |
| Vernalis | 52,000 | 99,000 | Vernalis | | Q |

# TABLE VIII-3

## RANKING OF SELECTED POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Approximate Basin Area (Mi^2) | Maximum Potential Storage Size (AF) | Location with Respect to Downstream Objective Flow Point In Downstream Order | Maximum Flow Excess (cfs) | Storage/Flow Excess | | Flow Excess /Basin Area | | Storage/Basin Area | | Total Ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Value (ac-ft/cfs) | Ranking | Value (cfs/Mi^2) | Ranking | Value (ac-ft/Mi^2) | Ranking | |
| Coloma Reservoir | 3 | 650 | 710,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | 1,092 | 8 | NA |
| Colusa Reservoir Complex | 18 | 60 | 3,300,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | 55,000 | 25 | NA |
| Cooperstown Reservoir | 43 | 125 | 609,000 | Tuolumne River at Modesto<br>San Joaquin River at Vernalis | 71,000 | 117 | 15 | 568 | 15 | 4,872 | 15 | 45 |
| Deer Creek Reservoir | 44 | 100 | 600,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | 6,000 | 17 | NA |
| Dry Creek Dam | 63 | NA | 444,000 | Kings River at Friant Kern Canal<br>San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 106 | 14 | NA | NA | NA | NA | NA |
| Fine Gold Creek Dam | 55 | 90 | 350,000 | San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 134 | 16 | 522 | 14 | 3,889 | 14 | 44 |
| Folsom Reservoir Enlargement | 5 | 1,875 | 365,000 | American River at Folsom Dam Outflow | 5,000 | 14 | 4 | 3 | 1 | 195 | 2 | 7 |
| Freemans Crossing Reservoir | 6 | 100 | 300,000 | Yuba River at Marysville<br>Feather River at Marysville<br>Feather River at Nicolaus | 5,000 | 17 | 5 | 50 | 9 | 3,000 | 11 | 25 |
| Garden Bar Reservoir | 7 | 300 | 245,000 | Feather River at Nicolaus | 5,000 | 20 | 7 | 17 | 3 | 817 | 4 | 14 |
| Garzas Reservoir | 30 | 75 | 1,754,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | 23,387 | 22 | NA |
| Glenn Reservoir Project | 22 | 700 | 8,206,000 | Sacramento River at Ord Ferry | 30,000 | 4 | 1 | 43 | 7 | 11723 | 19 | 27 |
| Hungry Hollow Reservoir | 65 | 10 | 800,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | 85,000 | 26 | NA |
| Lake Beryessa Enlargement | 24 | 560 | 11,700,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | 20,893 | 21 | 63 |
| Mill Creek Dam | 59 | 125 | 1,000,000 | Kings River at Friant Kern Canal<br>San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 47 | 10 | 376 | 11 | 8,000 | 18 | 39 |
| Millerton Lake Enlargement | 47 | 1,650 | 720,000 | San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 65 | 13 | 28 | 4 | 436 | 3 | 20 |
| Millville Reservoir | 10 | 125 | 206,000 | Sacramento River at Bend Bridge<br>Sacramento River at Ord Ferry | 60,000 | 291 | 20 | 480 | 12 | 1,648 | 9 | 41 |
| Montgomery Reservoir | 48 | 75 | 240,000 | Merced River at Cressey<br>San Joaquin River at Vernalis | 49,000 | 204 | 18 | 653 | 18 | 3,200 | 13 | 49 |
| Nashville Reservoir | 49 | 450 | 1,155,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | 2,567 | 10 | NA |

# TABLE VIII-3 (CONT.)

## RANKING OF SELECTED POTENTIAL WATER STORAGE PROJECTS

| Project Name | Reference No. | Approximate Basin Area (Mi^2) | Maximum Potential Storage Size (AF) | Location with Respect to Downstream Objective Flow Point In Downstream Order | Maximum Flow Excess (cfs) | Storage/Flow Excess | | Flow Excess /Basin Area | | Storage/Basin Area | | Total Ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Value (AF/cfs) | Ranking | Value (cfs/Mi^2) | Ranking | Value (AF/Mi^2) | Ranking | |
| Raise Terminus Dam | 61 | 1,200 | 1,200,000 | Kings River at Friant Kern Canal<br>San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 39 | 9 | 39 | 6 | 1,000 | 7 | 22 |
| Rogers Crossing Dam | 58 | 1,000 | 950,000 | Kings River at Friant Kern Canal<br>San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 49 | 12 | 47 | 8 | 950 | 6 | 26 |
| Shasta Lake Enlargement | 26 | 6,400 | 300,000 | Sacramento River at Bend Bridge<br>Sacramento River at Ord Ferry | 60,000 | 200 | 17 | 9 | 2 | 47 | 1 | 20 |
| Sites Reservoir | 27 | Unknown | 1,900,000 | No Downstream Objective Flow Point | NA | NA | NA | NA | NA | NA | NA | NA |
| Temperance Flat Dam | 53 | 1,600 | 1,400,000 | San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 34 | 8 | 29 | 5 | 875 | 5 | 18 |
| Thomes-Newville Reservoir | 28 | 60 | 3,080,000 | Sacramento River at Ord Ferry | 30,000 | 10 | 2 | 500 | 13 | 51,333 | 23 | 38 |
| Tuscan Buttes Reservoir | 12 | 100 | 5,500,000 | Sacramento River at Bend Bridge<br>Sacramento River at Ord Ferry | 60,000 | 11 | 3 | 600 | 16 | 55,000 | 24 | 43 |
| Waldo Reservoir | 13 | 100 | 300,000 | Yuba River at Marysville<br>Feather River at Marysville<br>Feather River at Nicolaus | 5,000 | 17 | 6 | 50 | 10 | 3,000 | 12 | 28 |
| Wing Reservoir | 14 | 50 | 244,000 | Sacramento River at Bend Bridge<br>Sacramento River at Ord Ferry | 60,000 | 246 | 19 | 1,200 | 19 | 4,880 | 16 | 54 |
| Yokohl Creek Dam | 62 | 75 | 970,000 | Kings River at Terminus<br>Kings River at Friant Kern Canal<br>San Joaquin River at Mendota Gage<br>San Joaquin River at El Nido<br>San Joaquin River at Newman<br>San Joaquin River at Vernalis | 47,000 | 48 | 11 | 627 | 17 | 12,933 | 20 | 48 |

## TABLE VIII-4
## SHORT-LISTED PROJECTS

| Proposed Project | Reason for Short Listing |
|---|---|
| Deer Creek Reservoir (44) | Potential for flood reduction on the Cosumnes River and the American River. Project could store water currently held in Folsom Lake leaving more capacity in Folsom for flood management. |
| Folsom Dam Height Increase (5) | The USACE has already studied the feasibility of increasing the height of Folsom Dam. However, it may be useful to include this project in the comprehensive study to demonstrate possible benefits. |
| Garden Bar Reservoir (7) | Flood reduction potential is difficult to assess due to the reservoir control point location. |
| Glenn Reservoir Project (22) | Ranks high based on the selection criteria. This project is located near the potential Thomas-Newville Reservoir (28). However, the Glenn Reservoir project would be larger and would have greater flood reduction potential. Therefore the Glenn Reservoir project was selected instead of the Thomas-Newville Reservoir. |
| Millerton Lake Enlargement (47) and Fine Gold Creek Dam (55) | Ranks high based on the selection criteria. The Temperance Dam project (53 is located directly upstream) would have similar results. Raising the height of the existing dam seems more feasible. |
| Montgomery Reservoir (48) | Potential flood reduction on the Merced River at Cressey. Diversions from Lake McClure appear to be feasible. |
| Raise Terminus Dam (61) | Ranks high based on the selection criteria. This project may have flood reduction potential for the Kings River at the Friant-Kern Canal. The analysis may include an assessment of off-stream storage generated by the potential Yokohl Creek Dam (62), and Dry Creek Dam (63). |
| Shasta Dam Height Increase (26) | Project ranks high based on the selection criteria. However, the existing capacity of Shasta Dam provides adequate management of most flood flows. Additional capacity may have little impact on flood flows at the Bend Bridge control point. |
| Sites Reservoir (27) | Has the potential for flood reduction on Stony Creek and the Sacramento River. Possible off-stream storage for the existing Stony Gorge, East Park, or Black Butte Reservoirs, and direct diversions from the Sacramento River. The results of this analysis would be similar for the proposed Colusa Reservoir Complex. |
| Tuscan Buttes Reservoir (12) | May have potential for flood reduction on the Sacramento River at Bend Bridge. This project is located near the potential Milleville Reservoir (10) and Wing Reservoir (14) projects. The most feasible of these projects would be included in the model. |

## ANALYSIS OF SCENARIOS

### Sacramento River Basin-Generic Off-Stream Storage Project

In the Sacramento River Basin, the regional flood damage reduction benefits of a generic off-stream storage reservoir were investigated (i.e. an off-stream storage project located at an unidentified site which could provide storage for water which is currently held at existing on-stream reservoirs). The generic project had the following characteristics:

- Maximum capacity of 500 TAF, 1,000 TAF, or 2,000 TAF
- Project to be filled by transfer of existing conservation storage in East Park, Stony Gorge, Shasta, Oroville, and/or Folsom reservoirs
- Project to have the capability for direct diversions from the Sacramento River below Shasta Dam (at Keswick) and Stony Creek below Black Butte Dam
- Diversions limited to a maximum of 3,000 cubic feet per second (cfs) from Stony Creek and 10,000 cfs from the Sacramento River.

The process used to distribute storage from the off-stream storage project among the candidate reservoirs is discussed in further detail below. Operations for the generic off-stream storage project were not modeled as an independent functioning system; the reservoir was assumed to have zero outflow until the maximum storage level was reached at which time it was assumed to pass inflow. The reservoir itself being generic, has no physical design criterion. Discharges from the generic off-stream storage reservoir were returned to the Sacramento River at Ord Ferry.

#### *HEC-5 Modeling*

The influences of the Sacramento River Basin generic off-stream storage project were analyzed using the HEC-5 models previously developed by the USACE. The models were updated as necessary to reflect the transfer of water from existing projects to the new storage site. The HEC-5 models were also updated to include direct diversions from the Sacramento River and Stony Creek as described below. Allocation of storage in the generic off-stream storage project was "optimized" for the occurrence of a 1-percent chance exceedence event as described below (i.e., the target event for flood damage reduction was the 1-percent chance exceedence flood). The HEC-5 models were run for 5 storm centerings (Stony Creek, Shasta, Oroville Dam, Folsom Dam, and Sacramento), as previously developed by the USACE.

**Storage Allocation** – Six reservoirs were selected for potential transfer of storage to the off-stream storage project. These included East Park, Stony Gorge, and Black Butte on the Stony Creek system, as well as Shasta, Oroville, and Folsom. As described above, three increments of storage (alternatives) in the generic off-stream reservoir were evaluated: 500 TAF, 1,000 TAF, and 2,000 TAF. The storage was allocated among the six reservoirs based on the current level of protection provided at the reservoir and existing storage capacity as documented in previous incremental analyses by the USACE. Priority in allocation was given to the reservoirs with the lowest levels of existing flood protection. Therefore, in each of the three alternatives the entire conservation storage in the Stony Creek system (67.4 TAF at East Park and Stony Gorge) was transferred to the generic off-stream storage project. In addition to this passive transfer of conservation storage, 156.6 TAF of active storage space in the project was allocated to accommodate a 3,000 cfs diversion from Stony Creek below Black Butte. The amount of active storage required for the diversion was determined from an initial simulation of the 1-percent chance exceedence event. Thus, the Stony Creek system was given the highest priority in allocating the additional storage for each alternative.

Considering the existing levels of protection, each of the three alternatives also included at least 50 TAF of transfer from conservation storage at Folsom Lake, which previous modeling had shown would allow Folsom outflows to meet objectives up to and including the annual 1-percent chance exeedence flood. This transfer was thus the second highest priority under each of the alternatives analyzed.

The remaining storage for each alternative was allocated based on the potential increase in flood protection or the expectation that the additional storage would help meet objective flows for larger events as determined from the previous incremental modeling analysis. Storage allocations from Shasta, Oroville, and Folsom; to the generic off-stream storage project for the three alternatives, are summarized in Table VIII-5.

**TABLE VIII-5**

**SACRAMENTO RIVER BASIN GENERIC OFF-STREAM RESERVOIR STORAGE ALLOCATION**

| | **Allocated Storage by Alternative (TAF)** | | |
|---|---|---|---|
| | **R01A** | **R02A** | **R03A** |
| Stony Creek Conservation Storage | 67.4 | 67.4 | 67.4 |
| Stony Creek Diversion Storage | 156.6 | 156.6 | 156.6 |
| Folsom Conservation Storage | 76.0 | 217.2 | 217.2 |
| Oroville Conservation Storage | 100.0 | 100.0 | 100.0 |
| Shasta Conservation Storage | 100.0 | 458.8 | 1458.8 |
| **Total Off-stream Storage Allocated** | **500.0** | **1,000.0** | **2,000.0** |

The 217.2 TAF transfer of storage from Folsom in alternatives R02A and R03A represents the entire conservation storage volume above the hydropower pool. The 100 TAF transfers from Oroville and Shasta represent the additional flood control storage required for the reservoirs to contain their respective 0.5-percent chance exceedence events, though objective flows would still be exceeded in both cases. Remaining storage in alternatives R02A and R03A was added to Shasta rather than Oroville because the incremental analyses indicated more opportunity to meet objective flows and control the annual 0.2-percent chance exceedence event. It should be noted that no active storage is reserved for the Sacramento River diversion, as the flows corresponding to a 1-percent chance exceedence event at Keswick do not exceed the 79,000 cfs objective.

**Headwater Model Modifications** – The Sacramento River Basin headwater HEC-5 model was modified to reflect changes to East Park and Stony Gorge conservation storage. For each of these projects, all storage above the minimum pool levels (5 TAF in East Park and 7.5 TAF in Stony Gorge) was transferred to the generic off-stream storage project. In addition to this transfer of storage, release schedules from each of these projects were modified to allow the projects to effectively use the additional storage for reducing flood peak discharges. Maximum non-spill releases from East Park were increased from 5 cfs to 1,500 cfs and from Stony Gorge were increased from 15 cfs to 7,500 cfs. These modifications allowed the projects to pass inflow during the early part of large storms, retaining most of the flood storage pool for use near the peak of the events. The releases were selected based on preliminary runs of the HEC-5 model and comparison of the timing of filling and spilling of the three Stony Creek projects.

It should be noted that neither the physical outlet capacity of the Stony Creek projects, nor the potential downstream impacts of higher flows were considered in setting the new maximum releases in the schedule. The modifications were designed to provide an “optimal” flood management configuration for 1-percent chance exceedence flood discharges from Black Butte dam. Sensitivity analyses indicated that the maximum discharges from Black Butte would not be significantly affected by moderate (up to 50 percent) reductions in the modeled peak outflow from the upstream projects. However, for purposes of the current analysis it was decided to use the discharges listed above.

After the revised headwaters model was run for each storm centering, a DSSMATH macro was run to calculate a revised top of conservation storage for reservoirs with credit space agreements. Modifications were made to the macro for Black Butte and Folsom conservation storage calculations to reflect storage transfers for each of the three alternatives.

**Mainstem Model Modifications** – Transfers of conservation storage for Shasta and Oroville were modeled by reducing the top of conservation storage, thus enlarging the flood control pool. Both the HEC-5 model and the input DSS files contain specifications for the top of conservation at these reservoirs. Conservation storage values were changed in both files and the initial storage volumes at each of the projects were changed so that the model would begin at the modified top of conservation storage.

Two diversions were added to the Sacramento River Basin model as part of the generic off-stream storage alternative. The Stony Creek diversion, assumed to be located just below Black Butte Reservoir, was configured to divert Stony Creek flows above 5,000 cfs (up to a maximum diversion of 3,000 cfs) to the off-stream reservoir. This allows flows in Stony Creek to be maintained at the non-damaging level for longer periods than are currently attained. To maximize the benefit of the diversion, the target releases from Black Butte were increased from 5,000 cfs to 8,000 cfs.

A 10,000 cfs diversion was also added to the HEC-5 model, corresponding to an assumed diversion from the Sacramento River at Keswick Dam (below Shasta Dam). Similar to the Stony Creek diversion, this diversion was configured to maintain flows below Keswick Dam at their target levels. As with the Stony Creek model, releases from Shasta Dam were modified to reflect the diversion capacity, with the current 79,000 cfs target increased to 89,000 cfs. Because the baseline HEC-5 model indicated that flows downstream of Keswick do not exceed 79,000 cfs in passing the annual 1-percent chance exceedence event, no storage space in the generic off-stream storage project was reserved for diversions from the Sacramento River. However, the assumed diversion from the Sacramento River at Keswick Dam is utilized in passing the 0.5- and 0.2-percent chance exceedence events.

Model results provide verification that the allocation of storage in each of the generic off-stream storage alternatives, were "optimized" for the 1-percent chance exceedence event. The model shows that for each project alternative, the off-stream reservoir just fills in simulating the 1-percent chance exceedence event for the Stony Creek centering. The maximum 1-percent chance exceedence storage is slightly less for each of the other storm centerings. The maximum storage values in the generic off-stream reservoir for various storm centerings are provided in Table VIII-6.

**TABLE VIII-6**

**MAXIMUM STORAGE IN THE SACRAMENTO RIVER BASIN GENERIC OFF-STREAM STORAGE PROJECT BASED ON HEC-5 SIMULATIONS OF THE 1% CHANCE EXCEEDENCE EVENT**

| | Maximum Storage by Alternative (TAF) | | |
|---|---|---|---|
| **Storm Centering** | **R01A (500 TAF)** | **R02A (1,000 TAF)** | **R03A (2,000 TAF)** |
| Stony | 499.4 | 999.4 | 1,999.4 |
| Shasta | 494.2 | 990.5 | 1,985.5 |
| Oroville | 421.9 | 919.8 | 1,919.3 |
| American | 489.9 | 989.9 | 1,989.9 |
| Sacramento | 489.5 | 988.5 | 1,988.5 |

***Results***

The effects of the off-stream storage alternatives were evaluated by comparing peak flows at four reservoir control points—Sacramento River at Keswick, Stony Creek below the proposed diversion (calculated as the difference of Black Butte outflow and Stony Creek diversion flow), Feather River below Oroville, American River below Folsom, and Sacramento River system at the latitude of Sacramento (Sacramento River at I Street gage plus Yolo Bypass at Interstate-80). Results of baseline and alternative scenarios for all 5 storm centerings are summarized in Tables VIII-7 through VIII-11. All three alternatives are effective in controlling the 1-percent chance exceedence flow to objective flows, except for the Stony Creek centering at Stony Creek and Oroville centering at Oroville simulations (see Tables VIII-8 and VIII-9). In the Oroville case, objective flows are exceeded by 1.5 percent.

## TABLE VIII-7

## MAXIMUM REGULATED FLOW FOR SACRAMENTO RIVER AT KESWICK, VARIOUS STORM CENTERINGS

| Reservoir Model | Maximum Regulated Flow By Percent Chance Exceedence (CFS) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
| AMR-BASE | 36,709 | 44,973 | 44,973 | 55,629 | 67,157 | 73,728 | 83,651 |
| AMR-R01A | 36,709 | 44,973 | 44,973 | 58,828 | 75,839 | 79,000 | 79,000 |
| AMR-R02A | 36,709 | 44,973 | 44,973 | 61,377 | 62,385 | 77,505 | 79,000 |
| AMR-R03A | 36,709 | 44,973 | 44,973 | 44,973 | 61,386 | 60,380 | 74,446 |
| ORO-BASE | 44,973 | 44,973 | 56,703 | 69,754 | 73,953 | 99,977 | 193,629 |
| ORO-R01A | 44,973 | 44,973 | 59,940 | 78,226 | 79,000 | 79,000 | 155,959 |
| ORO-R02A | 44,973 | 44,973 | 59,858 | 64,917 | 79,000 | 79,000 | 85,280 |
| ORO-R03A | 44,973 | 44,973 | 44,973 | 57,971 | 62,106 | 74,561 | 79,000 |
| SAC-BASE | 44,973 | 61,369 | 56,112 | 68,630 | 73,953 | 79,195 | 172,748 |
| SAC-R01A | 44,973 | 61,394 | 61,656 | 77,227 | 79,000 | 79,000 | 132,034 |
| SAC-R02A | 44,973 | 44,973 | 58,404 | 63,803 | 78,552 | 79,000 | 79,000 |
| SAC-R03A | 44,973 | 44,973 | 44,973 | 57,210 | 61,236 | 73,864 | 78,900 |
| SHA-BASE | 44,973 | 61,369 | 67,248 | 73,953 | 78,859 | 140,398 | 235,281 |
| SHA-R01A | 44,973 | 61,392 | 77,700 | 79,000 | 79,000 | 108,879 | 205,914 |
| SHA-R02A | 44,973 | 44,973 | 62,532 | 77,745 | 79,000 | 79,000 | 117,090 |
| SHA-R03A | 44,973 | 44,973 | 61,375 | 60,620 | 64,789 | 76,850 | 79,000 |
| STY-BASE | 42,324 | 44,973 | 54,966 | 68,929 | 73,953 | 79,127 | 184,482 |
| STY-R01A | 42,324 | 44,973 | 61,371 | 77,506 | 78,923 | 79,000 | 144,321 |
| STY-R02A | 42,324 | 44,973 | 58,159 | 64,096 | 78,866 | 79,000 | 79,000 |
| STY-R03A | 42,324 | 44,973 | 44,973 | 58,572 | 61,572 | 74,803 | 79,000 |

| Model Prefix | Storm Centering | Model Suffix | Model Alternative |
|---|---|---|---|
| AMR | American | BASE | Baseline scenario |
| ORO | Oroville Dam | R01A | 0.5 MAF off-stream storage reservoir |
| SAC | Sacramento | R02A | 1.0 MAF off-stream storage reservoir |
| SHA | Shasta | R03A | 2.0 MAF off-stream storage reservoir |
| STY | Stony | | |

Objective Flow= 79,000 cfs

## TABLE VIII-8

## MAXIMUM REGULATED FLOW FOR STONY CREEK BELOW PROPOSED DIVERSION*, VARIOUS STORM CENTERINGS

| Reservoir Model | Maximum Regulated Flow By Percent Chance Exceedence (CFS) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
| AMR-BASE | 5,000 | 9,837 | 12,450 | 14,950 | 20,000 | 47,823 | 63,293 |
| AMR-R01A | 5,000 | 7,903 | 9,450 | 9,450 | 11,950 | 11,950 | 46,783 |
| AMR-R02A | 5,000 | 7,903 | 9,450 | 9,450 | 11,950 | 11,950 | 46,783 |
| AMR-R03A | 5,000 | 7,903 | 9,450 | 9,450 | 11,950 | 11,950 | 46,783 |
| ORO-BASE | 3,110 | 5,000 | 5,242 | 9,629 | 12,450 | 14,950 | 20,000 |
| ORO-R01A | 3,334 | 5,000 | 5,619 | 7,827 | 9,450 | 9,450 | 11,950 |
| ORO-R02A | 3,334 | 5,000 | 5,619 | 7,827 | 9,450 | 9,450 | 11,950 |
| ORO-R03A | 3,334 | 5,000 | 5,619 | 7,827 | 9,450 | 9,450 | 11,950 |
| SAC-BASE | 5,000 | 11,858 | 12,450 | 14,950 | 18,091 | 45,789 | 60,330 |
| SAC-R01A | 5,000 | 8,646 | 9,450 | 9,450 | 11,950 | 11,950 | 44,007 |
| SAC-R02A | 5,000 | 8,646 | 9,450 | 9,450 | 11,950 | 11,950 | 44,007 |
| SAC-R03A | 5,000 | 8,646 | 9,450 | 9,450 | 11,950 | 11,950 | 44,007 |
| SHA-BASE | 5,242 | 5,242 | 12,450 | 14,950 | 14,950 | 20,000 | 53,885 |
| SHA-R01A | 5,619 | 5,619 | 8,964 | 9,450 | 10,951 | 11,950 | 19,800 |
| SHA-R02A | 5,619 | 5,619 | 8,964 | 9,450 | 10,951 | 11,950 | 19,800 |
| SHA-R03A | 5,619 | 5,619 | 8,964 | 9,450 | 10,951 | 11,950 | 19,800 |
| STY-BASE | 5,242 | 12,450 | 14,950 | 24,450 | 50,820 | 62,914 | 77,720 |
| STY-R01A | 5,619 | 9,450 | 11,950 | 11,950 | 17,000 | 46,377 | 66,148 |
| STY-R02A | 5,619 | 9,450 | 11,950 | 11,950 | 17,000 | 46,377 | 66,148 |
| STY-R03A | 5,619 | 9,450 | 11,950 | 11,950 | 17,000 | 46,377 | 66,148 |

| Model Prefix | Storm Centering | Model Suffix | Model Alternative |
|---|---|---|---|
| AMR | American | BASE | Baseline scenario |
| ORO | Oroville Dam | R01A | 0.5 MAF off-stream storage reservoir |
| SAC | Sacramento | R02A | 1.0 MAF off-stream storage reservoir |
| SHA | Shasta | R03A | 2.0 MAF off-stream storage reservoir |
| STY | Stony | | |

Objective Flow= 15,000 cfs
* Calculated as difference of Black Butte reservoir outflow and diversion flow (if any).

## TABLE VIII-9

## MAXIMUM OUTFLOW FOR OROVILLE DAM (FEATHER RIVER), VARIOUS STORM CENTERINGS

| Reservoir Model | Maximum Regulated Flow By Percent Chance Exceedence (CFS) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
| AMR-BASE | 60,000 | 60,000 | 100,000 | 150,000 | 150,000 | 150,000 | 224,695 |
| AMR-R01A | 60,000 | 60,000 | 100,000 | 139,263 | 150,000 | 150,000 | 187,516 |
| AMR-R02A | 60,000 | 60,000 | 100,000 | 139,263 | 150,000 | 150,000 | 187,516 |
| AMR-R03A | 60,000 | 60,000 | 100,000 | 139,263 | 150,000 | 150,000 | 187,516 |
| ORO-BASE | 60,000 | 100,000 | 150,000 | 150,000 | 150,459 | 165,708 | 326,818 |
| ORO-R01A | 60,000 | 100,000 | 136,199 | 150,000 | 150,363 | 152,100 | 288,654 |
| ORO-R02A | 60,000 | 100,000 | 136,199 | 150,000 | 150,363 | 152,100 | 288,654 |
| ORO-R03A | 60,000 | 100,000 | 136,199 | 150,000 | 150,363 | 152,100 | 288,654 |
| SAC-BASE | 60,000 | 100,000 | 150,000 | 150,000 | 150,000 | 150,000 | 292,115 |
| SAC-R01A | 59,826 | 100,000 | 141,510 | 150,000 | 150,000 | 150,000 | 258,501 |
| SAC-R02A | 59,826 | 100,000 | 141,510 | 150,000 | 150,000 | 150,000 | 258,501 |
| SAC-R03A | 59,826 | 100,000 | 141,510 | 150,000 | 150,000 | 150,000 | 258,501 |
| SHA-BASE | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 150,000 | 150,000 |
| SHA-R01A | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 136,632 | 150,000 |
| SHA-R02A | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 136,632 | 150,000 |
| SHA-R03A | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 136,632 | 150,000 |
| STY-BASE | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 150,000 | 150,000 |
| STY-R01A | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 136,632 | 150,000 |
| STY-R02A | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 136,632 | 150,000 |
| STY-R03A | 60,000 | 60,000 | 60,000 | 60,000 | 100,000 | 136,632 | 150,000 |

| Model Prefix | Storm Centering | Model Suffix | Model Alternative |
|---|---|---|---|
| AMR | American | BASE | Baseline scenario |
| ORO | Oroville Dam | R01A | 0.5 MAF off-stream storage reservoir |
| SAC | Sacramento | R02A | 1.0 MAF off-stream storage reservoir |
| SHA | Shasta | R03A | 2.0 MAF off-stream storage reservoir |
| STY | Stony | | |

Objective Flow= 150,000 cfs

## TABLE VIII-10

## MAXIMUM OUTFLOW FOR FOLSOM DAM (AMERICAN RIVER), VARIOUS STORM CENTERINGS

| Reservoir Model | Maximum Regulated Flow By Percent Chance Exceedence (CFS) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
| AMR-BASE | 37,183 | 115,000 | 115,000 | 115,000 | 120,169 | 301,121 | 532,698 |
| AMR-R01A | 35,490 | 115,000 | 115,000 | 115,000 | 115,000 | 220,991 | 529,475 |
| AMR-R02A | 33,240 | 115,000 | 115,000 | 115,000 | 115,000 | 127,272 | 502,082 |
| AMR-R03A | 33,240 | 115,000 | 115,000 | 115,000 | 115,000 | 127,272 | 502,082 |
| ORO-BASE | 22,058 | 92,364 | 115,000 | 115,000 | 115,000 | 125,709 | 412,227 |
| ORO-R01A | 20,971 | 90,991 | 115,000 | 115,000 | 115,000 | 115,000 | 365,523 |
| ORO-R02A | 19,303 | 88,179 | 115,000 | 115,000 | 115,000 | 115,000 | 225,993 |
| ORO-R03A | 19,303 | 88,179 | 115,000 | 115,000 | 115,000 | 115,000 | 225,993 |
| SAC-BASE | 33,938 | 112,364 | 115,000 | 115,000 | 115,000 | 204,615 | 493,030 |
| SAC-R01A | 32,849 | 110,765 | 115,000 | 115,000 | 115,000 | 138,853 | 481,887 |
| SAC-R02A | 30,924 | 107,567 | 115,000 | 115,000 | 115,000 | 115,000 | 384,190 |
| SAC-R03A | 30,924 | 107,567 | 115,000 | 115,000 | 115,000 | 115,000 | 384,190 |
| SHA-BASE | 18,755 | 18,755 | 37,183 | 87,308 | 115,000 | 115,000 | 115,000 |
| SHA-R01A | 17,887 | 17,887 | 35,490 | 85,984 | 115,000 | 115,000 | 115,000 |
| SHA-R02A | 16,604 | 16,604 | 33,240 | 83,250 | 115,000 | 115,000 | 115,000 |
| SHA-R03A | 16,604 | 16,604 | 33,240 | 83,250 | 115,000 | 115,000 | 115,000 |
| STY-BASE | 18,755 | 18,755 | 37,183 | 87,308 | 115,000 | 115,000 | 115,000 |
| STY-R01A | 17,887 | 17,887 | 35,490 | 85,984 | 115,000 | 115,000 | 115,000 |
| STY-R02A | 16,604 | 16,604 | 33,240 | 83,250 | 115,000 | 115,000 | 115,000 |
| STY-R03A | 16,604 | 16,604 | 33,240 | 83,250 | 115,000 | 115,000 | 115,000 |

| Model Prefix | Storm Centering | Model Suffix | Model Alternative |
|---|---|---|---|
| AMR | American | BASE | Baseline scenario |
| ORO | Oroville Dam | R01A | 0.5 MAF off-stream storage reservoir |
| SAC | Sacramento | R02A | 1.0 MAF off-stream storage reservoir |
| SHA | Shasta | R03A | 2.0 MAF off-stream storage reservoir |
| STY | Stony | | |

Objective Flow=115,000cfs

## TABLE VIII-11

## MAXIMUM REGULATED FLOW AT SACRAMENTO*, VARIOUS STORM CENTERINGS

| Reservoir Model | Maximum Regulated Flow By Percent Chance Exceedence (CFS) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 50% | 10% | 4% | 2% | 1% | 0.5% | 0.2% |
| AMR-BASE | 168,462 | 350,978 | 490,156 | 608,791 | 630,864 | 864,951 | 1,246,585 |
| AMR-R01A | 168,143 | 350,424 | 489,005 | 599,713 | 617,790 | 788,973 | 1,190,757 |
| AMR-R02A | 166,722 | 349,418 | 488,805 | 599,713 | 617,789 | 698,440 | 1,147,701 |
| AMR-R03A | 166,722 | 349,479 | 488,334 | 599,061 | 617,789 | 698,440 | 1,147,701 |
| ORO-BASE | 156,968 | 369,732 | 549,751 | 599,691 | 646,959 | 747,649 | 1,235,883 |
| ORO-R01A | 151,443 | 370,320 | 535,404 | 599,585 | 642,735 | 721,080 | 1,166,212 |
| ORO-R02A | 149,785 | 370,125 | 535,402 | 599,582 | 642,735 | 721,080 | 1,067,242 |
| ORO-R03A | 149,785 | 369,979 | 535,402 | 599,582 | 642,735 | 721,080 | 1,067,242 |
| SAC-BASE | 180,195 | 423,140 | 583,813 | 618,412 | 664,200 | 830,053 | 1,313,486 |
| SAC-R01A | 177,403 | 423,732 | 570,694 | 617,695 | 652,256 | 757,366 | 1,256,611 |
| SAC-R02A | 175,851 | 423,752 | 570,694 | 617,694 | 652,256 | 736,035 | 1,198,006 |
| SAC-R03A | 175,851 | 423,661 | 570,694 | 617,694 | 652,256 | 736,035 | 1,198,006 |
| SHA-BASE | 169,655 | 202,237 | 249,983 | 367,765 | 508,164 | 641,958 | 678,638 |
| SHA-R01A | 168,777 | 201,455 | 243,411 | 366,970 | 505,299 | 621,166 | 675,369 |
| SHA-R02A | 167,986 | 200,534 | 240,595 | 366,810 | 504,079 | 621,166 | 672,213 |
| SHA-R03A | 168,016 | 200,007 | 240,595 | 366,810 | 504,079 | 621,166 | 670,853 |
| STY-BASE | 162,495 | 219,706 | 271,312 | 393,306 | 535,000 | 675,632 | 714,483 |
| STY-R01A | 161,608 | 217,586 | 264,298 | 390,869 | 530,547 | 654,899 | 695,994 |
| STY-R02A | 160,663 | 216,816 | 263,718 | 391,036 | 529,327 | 654,899 | 695,843 |
| STY-R03A | 160,663 | 216,637 | 263,408 | 391,036 | 529,327 | 654,899 | 695,843 |

| Model Prefix | Storm Centering | Model Suffix | Model Alternative |
|---|---|---|---|
| AMR | American | BASE | Baseline scenario |
| ORO | Oroville Dam | R01A | 0.5 MAF off-stream storage reservoir |
| SAC | Sacramento | R02A | 1.0 MAF off-stream storage reservoir |
| SHA | Shasta | R03A | 2.0 MAF off-stream storage reservoir |
| STY | Stony | | |

* Calculated as sum of Sacramento River at I St. Gage and Yolo Bypass at I-80.

The analysis indicated that there are likely to be significant benefits associated with storage projects on tributary systems, especially Stony Creek. Models showed that exceedence of the 15,000 cfs objective flow below the proposed Stony Creek diversion structure is reduced from around a 4-percent chance exceedence event to at least a 2-percent chance exceedence event under project conditions. The peak flow associated with a 1-percent chance exceedence is reduced from 50,820 cfs to 17,000 cfs (a decrease of 67 percent). These benefits rely on the diversion capacity and modification of upstream storage facilities.

The reduction in flood potential for the index point on the Sacramento River system at the latitude of Sacramento was smaller in magnitude than for Stony Creek. For the annual 1-percent chance exceedence storm runoff, flows at Sacramento would be reduced from 0.65 percent to 2 percent depending on the storm centering, with minimal difference between alternative scenarios. The largest reductions are seen for the 0.5-percent chance exceedence events, particularly for the American and Sacramento storm centerings. This benefit appears primarily to be a result of substantial reductions in flows below Folsom. This is probably due to the location of the American River confluence with respect to the Sacramento index point. This may indicate that greater benefit could be achieved by altering the reservoir releases from Shasta, Oroville, and/or Folsom (i.e. redefining reservoir operations to reflect additional storage). With the exception of these two storm centerings, there is very little difference in the performance of the three alternative off-stream reservoir projects.

In the existing condition, the Shasta and Oroville projects control discharges associated with the 1-percent chance exceedence event to objective flows, thus the proposed project alternatives have the most apparent benefit at the 0.5-percent chance exceedence level. The 0.5-percent chance exceedence flow at Keswick Dam with the Shasta Storm runoff centering would be reduced from 140,398 cfs to less than the 79,000 cfs objective flow for Alternatives R02A and R03A. The 0.5-percent chance exceedence flow for the R01A alternative would be reduced to108,879 cfs.

### San Joaquin Basin-Friant Projects

In the San Joaquin River Basin, the regional flood damage reduction benefits of a suite of three potential reservoir projects near Friant Dam were investigated. The projects include raising Friant Dam, construction of Temperance Flat dam on the San Joaquin River upstream of Friant Dam, and construction Fine Gold Dam on Fine Gold Creek upstream of Friant Dam. Each project was evaluated separately, and additional models were used to simulate a combination of projects.

Analyses were conducted for the following seven cases:

- FRI-R01A evaluated doubling the existing flood space in Millerton Lake by increasing the height of Friant Dam 32 feet.
- FRI-R02A evaluated raising Friant Dam 20 feet and using all of the additional storage as flood space.
- FRI-R03A evaluated raising Friant Dam 20 feet and apportioning the additional storage between conservation and flood space based on the existing proportion.

- TMP-R01A evaluated construction of Temperance Flat Dam upstream of Friant Dam and using all of the additional storage for flood management.
- FNG-R01A evaluated construction of a 350 TAF Fine Gold off-stream reservoir located on Fine Gold Creek upstream of Friant Dam.
- SJQ-R01A evaluated a combination of the FRI-R01A, TMP-R01A, and FNG-R01A scenarios.
- SJQ-R02A evaluated a combination of the FRI-R01A, and FNG-R01A cases.

The process used to evaluate these cases is discussed in further detail below. Operations for the Fine Gold off-stream storage project were not modeled explicitly as flows must be pumped into the project. It was assumed that pumped diversions from Millerton Lake to the Fine Gold reservoir might not be feasible during flood flows. Therefore, it was assumed that Millerton Lake water would be pumped to the Fine Gold reservoir prior to the flood season allowing conservation storage in Millerton Lake to be reduced by an equal amount. Thus, the Fine Gold Creek project was assessed by reducing the amount of conservation storage in Millerton Lake and allocating this space to the flood control pool.

### *HEC-5 Modeling*

Each of the cases described above was analyzed using HEC-5 models previously developed by the USACE. The models were updated as necessary to reflect the project characteristics. The HEC-5 models were run with the Friant and El Nido storm centerings, previously developed by the USACE for the Sacramento San Joaquin Comprehensive Study. Model results were tabulated and compared with the base condition for the 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedence storm runoff events.

Several of the project cases required modifications to the top of conservation storage at Friant Dam. Both the HEC-5 model and the input DSS files contain specifications for the top of conservation at this reservoir. The top of conservation at Friant Dam is subject to a credit space agreement, and is calculated using the DSS input file containing reservoir inflows and a DSSMATH macro depending on a base value and the storage in Mammoth reservoir. The macro was modified for each project case that required changing the top of conservation at Millerton Lake. Initial storage volumes were adjusted in the HEC-5 model as necessary.

**FRI-R01A** – The existing model of Friant Dam was modified to reflect a 32-foot increase of the spillway crest elevation. No modifications were made to the top of conservation. This increased the volume of the flood pool from 170 TAF to 340 TAF (assuming a minimum top of conservation storage of 350.5 TAF from the credit space agreement). The increased storage was based on the elevation-storage-area curves presented in the URS study (FWUA and NRDC, 2000). The model was used to generate outflows for the Friant and El Nido storm centerings.

**FRI-R02A** – The existing model of Friant Dam was modified to reflect a 20-foot increase of the spillway crest elevation. No modifications were made to the top of conservation. This increased the maximum volume of the flood pool from 170 TAF to 275 TAF (assuming a minimum top of conservation storage of 350.5 TAF from the credit space agreement). The model was used to generate outflows for the Friant and El Nido storm centerings.

**<u>FRI-R03A</u>** – The existing model of Friant Dam was modified to reflect a 20-foot increase of the spillway crest elevation while maintaining the same proportion of conservation and flood storage. The maximum volume of the flood pool was increased from 170 TAF to 188 TAF. In order to maintain the existing proportion between conservation storage and flood space, 87.5 TAF was assigned to conservation storage in both the HEC-5 model and the DSS input file for each storm centering. The model was used to generate outflows for the Friant and El Nido storm centerings.

**<u>TMP-R01A</u>** – The existing HEC-5 model was modified, by adding the Temperance Flat reservoir upstream of Friant Dam. The model was based on the elevation-storage-area curves presented in the URS study (FWUA and NRDC, 2000). The outlet and spillway configurations were copied from the Friant Dam model and elevations were adjusted accordingly. The inactive pool was defined at an elevation of 650 feet with storage of 80,000 acre-feet. All storage except for the inactive pool was allocated to flood storage by setting the top of buffer and top of conservation storage at the top of inactive pool. The total volume at the top of flood pool is defined as 1,368,000 acre-feet at an elevation of 993 feet. The Temperance Flat model was set to operate in tandem with Friant Dam (i.e., the model maintains the same percentage of encroachment into the flood pool at both reservoirs). The model was used to generate outflows for the Friant and El Nido storm centerings.

**<u>FGD-R01A</u>** – As discussed above, operations for the Fine Gold off-stream storage project were not modeled explicitly. It was assumed that pumped diversions from Millerton Lake to Fine Gold reservoir would be used to fill Fine Gold reservoir prior to the flood season and Millerton Lake would enter the flood season with conservation storage reduced by an equal amount. The effect of the Fine Gold reservoir project was assessed, by increasing the amount of flood control storage at Friant Dam. The existing HEC-5 model was modified, by changing the top of conservation storage at Friant and decreasing conservation storage in the DSS input files for each storm centering by 275 TAF. This was the difference between Fine Gold's total storage of 350 TAF and inactive storage of 75 TAF as described in the URS study (FWUA and NRDC, 2000). The model was used to generate outflows for the Friant and El Nido storm centerings.

**<u>SJQ-R01A</u>** – This model was created by combining the models developed for Temperance Flat (TMP-R01A), the 32-foot Friant Dam raise (FRI-R01A), and Fine Gold (FNG-R01A). The model was used to generate outflows for the Friant and El Nido storm centerings.

**<u>SJQ-R02A</u>** – This model was created, by combining the models developed for the 32-foot Friant Dam raise (FRI-R01A), and Fine Gold (FNG-R01A). The model was used to generate outflows for the Friant and El Nido storm centerings.

### *Results*

The effects of the storage alternatives were evaluated by comparing peak flows at two reservoir control points—San Joaquin River at Friant, and San Joaquin River at El Nido. Maximum regulated outflows for the 50-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedence events at Friant Dam with the Friant Storm centering are provided in Table VIII-12. Maximum regulated flows for the same events for the San Joaquin River at El Nido with the El Nido storm centering are provided in Table VIII-13.

# TABLE VIII-12

## MAXIMUM REGULATED FLOW, SAN JOAQUIN RIVER AT FRIANT DAM, FRIANT STORM CENTERING

| **Reservoir Model** | **Maximum Regulated Flow By Percent Chance Exceedence (CFS)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| FRI-Base | 3,032 | 7,972 | 9,001 | 25,481 | 71,093 | 108,585 | 139,402 |
| FRI-R01A | 2,446 | 7,982 | 8,000 | 8,000 | 10,878 | 52,946 | 125,723 |
| FRI-R02A | 2,565 | 8,000 | 8,000 | 8,194 | 26,583 | 63,867 | 137,026 |
| FRI-R03A | 2,896 | 7,976 | 8,000 | 20,027 | 55,691 | 109,121 | 139,645 |
| TMP-R01A | 2,204 | 6,259 | 7,905 | 8,000 | 8,000 | 8,000 | 8,000 |
| FGD-R01A | 2,358 | 7,904 | 8,000 | 8,000 | 8,000 | 15,770 | 83,071 |
| SJQ-R01A | 3,041 | 4,418 | 6,197 | 7,353 | 8,000 | 8,000 | 8,000 |
| SJQ-R02A | 2,276 | 6,939 | 8,000 | 8,000 | 8,000 | 8,000 | 26,677 |

| Hydraulic Model | Model Description |
|---|---|
| FRI-Base | Base hydraulic model, Friant Storm Centering |
| FRI-R01A | Double the flood space in Millerton Lake (32-Foot Dam Raise) |
| FRI-R02A | Raise Friant Dam 20-Feet and use all additional storage as flood space |
| FRI-R03A | Raise Friant Dam 20-Feet and maintain same proportion of conservation space to flood space |
| TMP-R01A | Add Temperance Flat Dam upstream of Friant, all additional storage used as flood space |
| FGD-R01A | Add Fine Gold Off-stream Reservoir, conservation storage at Friant reduced by 275,000 acre feet. |
| SJQ-R01A | Combine FRI-R01A, TMP-R01A, and FGD-R01A |
| SJQ-R02A | Combine FRI-R01A, and FGD-R01A |

Objective Flow = 8,000 cfs

# TABLE VIII-13

# MAXIMUM REGULATED FLOW, SAN JOAQUIN RIVER AT EL NIDO, EL NIDO STORM CENTERING

| **Reservoir Model** | **Maximum Regulated Flow By Percent Chance Exceedence (CFS)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **50%** | **10%** | **4%** | **2%** | **1%** | **0.5%** | **0.2%** |
| NID-Base | 3,694 | 14,596 | 20,247 | 28,812 | 50,286 | 77,953 | 115,431 |
| FRI-R01A | 3,610 | 14,294 | 19,090 | 22,544 | 24,623 | 41,019 | 93,881 |
| FRI-R02A | 3,633 | 14,410 | 19,111 | 22,649 | 31,482 | 55,379 | 104,372 |
| FRI-R03A | 3,683 | 14,591 | 19,033 | 24,597 | 47,042 | 74,100 | 114,704 |
| TMP-R01A | 3,183 | 11,615 | 18,941 | 22,409 | 24,762 | 25,362 | 42,315 |
| FGD-R01A | 3,603 | 13,345 | 18,911 | 22,380 | 24,773 | 26,656 | 76,740 |
| SJQ-R01A | 3,185 | 11,551 | 16,917 | 21,973 | 24,698 | 25,342 | 42,315 |
| SJQ-R02A | 3,579 | 12,698 | 18,864 | 22,521 | 24,631 | 25,363 | 44,647 |

| Hydraulic Model | Model Description |
|---|---|
| FRI-Base | Base hydraulic model, Friant Storm Centering |
| FRI-R01A | Double the flood space in Millerton Lake (32-Foot Dam Raise) |
| FRI-R02A | Raise Friant Dam 20-Feet, all additional storage used as flood space |
| FRI-R03A | Raise Friant Dam 20-Feet and maintain same proportion of conservation space to flood space |
| TMP-R01A | Add Temperance Flat Dam upstream of Friant, all additional storage used as flood space |
| FGD-R01A | Add Fine Gold Off-stream Reservoir, conservation storage at Friant reduced by 275,000 acre feet. |
| SJQ-R01A | Combine FRI-R01A, TMP-R01A, and FGD-R01A |
| SJQ-R02A | Combine FRI-R01A, and FGD-R01A |

Objective Flow = 17,000 cfs

**FRI-R01A** – Under existing conditions, the objective flow at Friant Dam is exceeded around the occurrence of a 10-percent chance exceedence event. Raising Friant Dam by 32 feet and using all of the additional space for the flood pool (FRI-R01A) reduces releases to less than the objective flow through the 2-percent chance exceedence event. The FRI-R01A alternative also decreases the peak outflow during the 1-percent chance exceedence event from 71,093 cfs to 10,878 cfs, or approximately 85 percent. For the simulated 0.5- and 0.2-percent chance exceedence events this percentage decreases to 51 percent and 10 percent, respectively. At the El Nido control point, the objective flow is exceeded above the 10-percent chance exceedence event for the El Nido storm centering under existing conditions. For the FRI-R01A alternative, the objective flow is still exceeded above a 10-percent chance exceedence event. However, the alternative decreases the peak outflow during the 1-percent chance exceedence event from 50,286 cfs to 24,623 cfs, or approximately 51 percent. For the 0.5- and 0.2-percent chance exceedence events the percentage decreases to 47 percent and 19 percent, respectively.

**FRI-R02A** – Raising Friant Dam by 20 feet and using all of the additional space for the flood pool (FRI-R02A) reduces releases to less than the objective flow through the 4-percent chance exceedence event. The objective flow is exceeded slightly at the 2-percent chance exceedence event, but the peak outflow is decreased from 25,481 in the base condition to 8,194 cfs, or 68 percent. For larger events, this percentage decreases. For the 0.2-percent chance exceedence event, the peak outflow is decreased from 139,402 cfs to 137,026 cfs, a 2-percent decrease. At the El Nido control point and El Nido storm centering, performance is similar to the FRI-R01A alternative for the 4-percent chance exceedence event. However, reductions in peak flow from the base conditions are lower than the FRI-R01A alternative for larger events.

**FRI-R03A** – Raising Friant Dam by 20 feet and apportioning the additional space between conservation storage and flood space (FRI-R01A) provides the least amount of flood damage reduction potential. This alternative meets the objective flow target for events including and occurring more frequently than the 4-percent chance exceedence event and decreases the peak outflow of Friant Dam during the 4-percent chance exceedence event from 25,481 to 20,027 cfs, or 21 percent. The performance at El Nido is similar to the FRI-R01A and FRI-R02A alternatives through the 4-percent chance exceedence event, but lower for less frequent events.

**TMP-R01A** – The TMP-R01A model shows that the 1,368,000 acre-feet of additional storage provided by Temperance Flat Dam allows reduction of Friant outflows to target levels for all events modeled (i.e., up to the 0.2-percent chance exceedence event). The Temperance Flat alternative only meets the objective flow target with the occurrence of a 50-percent chance exceedence through 10-percent chance exceedence events at the El Nido index point. However, this alternative provides substantial peak reduction for larger events. For example, the peak associated with the occurrence of a 0.2-percent chance exceedence event is reduced from 115,431 cfs to 42,315 cfs.

**FNG-R01A** – The FNG-R01A model shows that the increase in flood storage at Friant Dam associated with a transfer of conservation space to Fine Gold Dam reduces releases to less than the objective flow through the 1-percent chance exceedence event. The FGD-R01A alternative also decreases the peak outflow during the 0.2-percent chance exceedence event from 139,402 cfs to 83,071 cfs, or approximately 40 percent. The FNG-R01A alternative only meets the objective flow target for the 50- through 10-percent chance exceedence events at the El Nido index point. However, this alternative provides substantial peak reduction for larger events. For example, the peak associated with the0.2-percent chance exceedence event is reduced from 115,431 cfs to 76,740 cfs.

**SJQ-R01A** – The combination of FRI-R01A, TMP-R01A, and FNG-R01A alternatives (SJQ-R01A) produces results similar to the TMP-R01A alternative for the Friant Dam control point. The Temperance Flat Dam is sufficiently large enough to reduce all of the Friant outflows to target levels for all of the events modeled. The additional storage capacity modeled in the SJQ-R01A alternative obtained from raising Friant Dam 32 feet and Fine Gold Dam provides no increase in flood reduction potential for any of the events at the Friant Dam control point. At the El Nido index point, the SJQ-R01A model meets the objective flow target through the 4-percent chance exceedence event. Peak flows at the El Nido index point are similar to the TMP-R01A alternative for the larger events.

**SJQ-R02A** – The SJQ-R02A model shows that a combination of a 32-foot raise at Friant Dam and an additional 275 TAF of storage facilitated by Fine Gold reduces peak outflows from Friant to the target flows for events up to the 0.5-percent chance exceedence event. For the 0.2-percent chance exceedence event, the alternative reduces the peak discharge by approximately 80 percent. This alternative only meets the objective flow target for the 50- through 10-percent chance exceedence events at the El Nido index point. However, the alternative provides substantial peak reduction for larger events. For example, the peak associated with the occurrence of a 0.2-percent chance exceedence event is reduced from 115,431 cfs to 44,647 cfs.

## SUMMARY

The preceding text documents the study undertaken to investigate the potential for flood damage reduction in the Sacramento and San Joaquin River Basins as a result of reservoir raises and/or the construction of new on-stream and off-stream storage projects. Potential projects, proposed primarily for water supply objectives, were identified and ranked for their potential flood damage reduction benefits using a screening process. The scenarios to be modeled were selected based on this ranking.

Two alternative scenarios, an off-stream storage project in the Sacramento River Basin and a suite of potential flood damage reduction measures in the vicinity of Friant Dam in the San Joaquin River Basin, were evaluated. Each of these scenarios consisted of multiple modifications to the existing flood damage reduction facilities in these basins. For purposes of evaluating their potential benefits, the storage associated with proposed projects was investigated for flood damage reduction benefits without regard to water supply objectives. Additional project formulation and analysis would be required to assess the feasibility and effectiveness of particular projects, and to determine the optimal combination of water supply and flood damage reduction benefits.

Based on the results of this effort, the modeled off-stream project in the Sacramento system did not result in any significant flood flow reductions at the downstream location near Sacramento. This is likely due to a number of factors including: the effect of tributary inflows downstream of the projects evaluated for this study; the difference in timing between the tributary systems where flows are reduced (e.g. Stony Creek) and the main stem flooding; and the fact that Oroville and Shasta already control flows occurring as frequent or more frequently than the 1-percent chance exceedence event to their target levels. It is possible that more significant reductions in flood flows at Sacramento could be achieved by modifying flood operations at Shasta and/or Oroville in conjunction with the proposed off-stream storage project. Optimizing use of the enlarged flood control space could allow objective flows to be reduced, resulting in lower flows at the Sacramento model index point. The analysis did indicate that there are likely to be significant benefits associated with storage projects on tributary systems such as Stony Creek.

It appears that projects on the San Joaquin River may warrant further review. None of the alternatives modeled controlled flows at El Nido to the objective flow of 17,000 cfs for events greater than an annual 4-percent chance exceedence event. However, all of the alternatives offer significant flow reductions at El Nido for the 4- and 1-percent chance exceedence events; the Temperance Flat and Fine Gold alternatives offer continued significant flow reductions for the 0.5-percent chance exceedence event; and the Temperance Flat alternative provides significant flow reductions for even the 0.2-percent chance exceedence event. Evaluation of the project-related costs and potential flood damage reduction benefits was not undertaken as part of this study. Neither was an independent assessment of the feasibility or constraints on the development of these projects. However, based on the results of this study, it would appear that further review of these or similar projects are warranted.

As noted above, this study was intended to provide an initial evaluation of the potential for flood damage reduction through raising existing dams or construction of new on-stream and off-stream storage projects. The results of this study indicate that projects that have been proposed for water supply or other purposes may be able to provide flood damage reduction benefits as well. Further modeling and a more detailed evaluation of the feasibility of particular projects, appears to be justified.